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Magnetic Survey of Eldorado and Langmuir Townships

District of Cochrane

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ONTARIO
MINISTRY OF NORTHERN DEVELOPMENT
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By

W. Moon

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CHART

(back pocket)

Eldorado and Langmuir Townships – Vertical magnetic contours and geological interpretation of magnetic survey.

Scale 1 inch to ½ mile or 1:31,680.

ABSTRACT

In this report, ground vertical magnetic field contour maps, overburden data, magnetic susceptibilities of typical rocks, and the interpretation of the data are presented for Eldorado and Langmuir Townships (which are located about 15 miles (25 km) southeast of Timmins), in the district of Cochrane, Ontario.

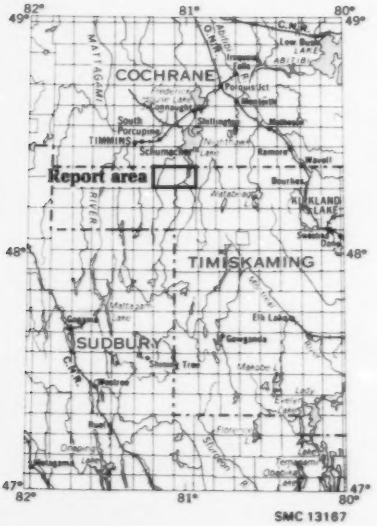

Figure 1–Key map showing location of Eldorado and Langmuir Townships. Scale, 1 inch to 50 miles (1:3,168,000).

All rocks in the area are of Precambrian age and the area is underlain by metavolcanics, metasediments and felsic and ultramafic intrusive rocks. North or northeast-trending diabase dikes are numerous and intrude the metavolcanics, metasediments and intrusive rocks. The high magnetic susceptibility of ultramafic rocks and diabase dikes make the vertical magnetic contour map very complicated. Cobalt type conglomerate, with low magnetic susceptibility, occurs in the southwestern part of Langmuir Township. In some parts of the survey area the sand and gravel overburden has a fairly high magnetic susceptibility. The effect of thickness and magnetic properties of the overburden on the magnetic anomaly interpretation are investigated. For a few structurally important magnetic anomalies, numerical quantitative interpretation is attempted using computer programs and magnetic susceptibility data. The spatial frequency spectra of selected cross sections of the survey area were obtained from the depth estimations of the magnetic anomaly units. Because of the economic importance of the area, the current mining and exploration activities are described briefly.

Magnetic Survey

of

Eldorado and Langmuir Townships

District of Cochrane

by

W. Moon[1]

INTRODUCTION

Location and Means of Access

Langmuir Township is located about 20 miles (32 km) southeast of Timmins, Ontario. The northwestern part of the township may be reached by a new Noranda-Inco mines road, and the central and southern part of the township may be reached by boat via Night Hawk Lake (St. Peter Bay), Night Hawk River and Forks River. Due to the recent discovery of nickel deposits on the Noranda-Inco property and the following staking rush, there are numerous trails throughout the township. All township lines were well cut and were used as access to various parts of the township.

Access to Eldorado Township is more difficult. There is only one dirt road, and this extends north-south along the eastern part of the township. In the early spring, or after considerable rain, the road is best traversed by a four-wheel drive vehicle.

The Redstone River in the western part of the township is navigable by canoe but there are numerous beaver dams, log jams, and rapids.

The southern and eastern township boundary lines are well cut and can be used to reach to the southern and eastern part of the township. The northern and western township boundaries are not cut well and can be located only by recent claim lines. The fastest and easiest way to reach the various parts of Eldorado Township is by helicopter.

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[1]Geophysicist, Geological Surveys Section, Geological Branch, Ontario Division of Mines, Toronto. Manuscript accepted for publication by the Chief Geologist, 10 October 1972.

Previous Work

Most recently, Pyke (1970) described in detail the geology of Langmuir Township. Geological features of Eldorado Township were also mapped in detail by Pyke (1969).

In 1970, an aeromagnetic map at a scale of one inch to one mile (1:83,360) was published by the Ontario Department of Mines and Geological Survey of Canada. During the period 1967 to 1971, The International Nickel Company of Canada Limited carried out an extensive ground geophysical survey which included a ground vertical field magnetic survey, and a ground electromagnetic survey. Parts of the ground magnetic survey data of the area were submitted for assessment work credit and are used in this report.

Considerable exploration work has been done by various mining companies in Langmuir and Eldorado Townships dating back to the early 1900s. It is described by Pyke (1970, 1972).

Acknowledgments

The geophysical field work for this report was initially planned and started by R. S. Middleton, then geophysicist with the Ontario Department of Mines and Northern Affairs. Subsequent to June 15, 1971, W. Moon assumed responsibility for the project.

The author was assisted in the field by P. Mark, senior assistant, and P. Strandberg and D. Conley, junior assistants. P. Mark also prepared the contour maps and diagrams accompanying this report. The author is grateful to Mr. H. F. Stewart of The International Nickel Company of Canada Limited, and Mr. E. Gallo of Noranda Exploration Company Limited, for making available numerous ground magnetic survey data in the area and information on the Noranda-Inco mine, presently being developed in Langmuir Township.

MAGNETIC SURVEY

Survey Method

A ground vertical field magnetic survey was carried out using one Sharp MF-1-100 and two McPhar M-700 fluxgate magnetometers. The diurnal changes in the earth's magnetic field were recorded to an accuracy of $\pm$ 10 gammas utilizing one of the McPhar magnetometers and a Rustrak model 88 recorder.

Magnetic surveys filed for assessment credit with the Ontario Division of Mines were utilized in producing the accompanying magnetic contour map. Corrections for relative differences between company survey values and the present survey values were obtained by reoccupying a number of company stations. An arithmetic average of the differences was then applied to reduce the company survey to a common base. The grids that could not be tied-in with an accuracy of $\pm$25

gammas were resurveyed using the original grids. The present survey is based on the value of +1,000 gammas of the Bristol-Ogden magnetic base station on Highway 101. This Bristol-Ogden magnetic base station was established by S. A. Ferguson (1957) as the ODM central magnetic base station. It is also described in the Mining Act (ODM 1969, p.XXXI).

The areas not covered by company surveys were traversed at 600- to 800-foot (183 to 244 m) line intervals. The traverses were arranged at right angles to the general trend of the regional geology wherever possible. Readings were taken every 100 feet (30 m). A compass and chain technique was used to run the traverses, and aerial photographs (1 inch to 860 feet = 1:10,320) were used to locate the traverse line. Chainage errors averaged less than 100 feet (30 m) in a mile (1.6 km) and were distributed between known points on the traverse. All the readings taken in the field were corrected for diurnal variation and plotted on the base map for final contouring.

Magnetic Properties of Rocks

Magnetic susceptibility measurements were made of all major rock types occurring in the survey area. About three hundred susceptibility readings were taken from diamond drill core samples and two hundred were obtained on outcrop in the field using a Bison 3120 "in situ" coil. Another 27 susceptibility measurements were made on samples from the areas of thick overburden in Eldorado and Langmuir Townships. The histograms of the susceptibilities for bulk rock formations are presented in semi-logarithmic form. Because of this mode of presentation, the area density on the histograms is not uniform.

The most common ferromagnetic minerals in the rocks of the survey area are magnetite and pyrrhotite. According to Pyke (1970), the serpentinized peridotite-pyroxenite has secondary magnetite contents from 2 to 10 percent, and related gabbroic intrusives have up to 3 percent magnetite. The diabase dikes (both N-S dikes and NE-SW dikes) have magnetite contents ranging from 4 percent to 8 percent by volume. As is the general case, felsic intrusives have very little ferromagnetic mineral content.

Wide variations of magnetic susceptibility are found in the various rock types, partly because of fluctuations of ferromagnetic mineral contents and partly because of metamorphic alteration of these minerals. R. S. Middleton (1974) also reported variations of magnetic susceptibility caused by changes in the chemical composition of ferromagnetic minerals.

Measurements of remanent magnetism were not carried out in the survey area. However, the remanent magnetism studies for the rocks in Robb and Jamieson Townships by R. S. Middleton (1973) and those for Precambrian metavolcanic complexes in the Kenora area by D. H. Hall (1968) proved that the remanence in the metavolcanics and felsic intrusives is not significant. Moreover, though the remanent magnetism in the mafic intrusives is significant, it is generally aligned in the direction of the present earth's field and not very important in the interpretation of the survey results.

The magnetic susceptibilities of the individual rock types are illustrated below in separate histograms.

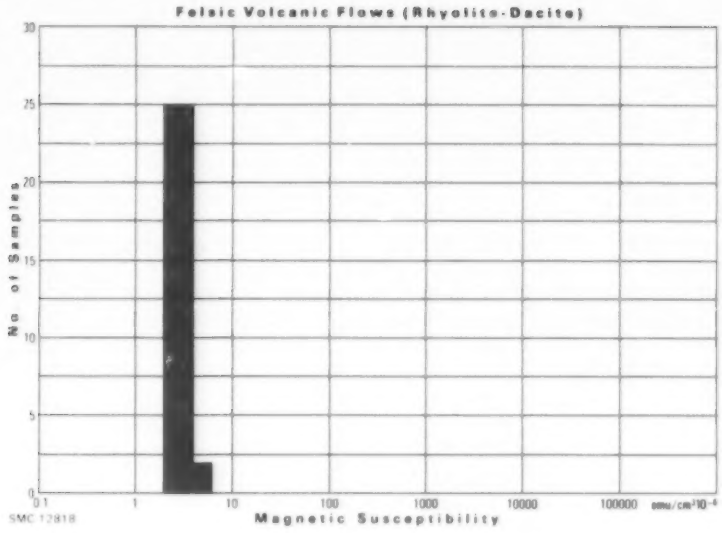

Figure 2–Magnetic susceptibility of felsic metavolcanics (rhyolite and dacite).

In Figure 2, the magnetic susceptibility readings of rhyolite and dacite are shown. Twenty-seven samples were tested; twenty-five were drill core samples, and two were outcrop determinations. The dacite samples are light grey-green fine-grained massive volcanic flows with a slight foliation. There are no dacites with porphyritic texture among the samples. The rhyolite samples are light to dark grey, very fine grained massive flows. The range of magnetic susceptibility is very narrow from 2×10^{-6} cgs units to 6×10^{-6} cgs units, which may indicate that the ferromagnetic minerals (or chemical components) were largely removed by marked differentiation of the parental magma.

The magnetic susceptibilities of the felsic to intermediate pyroclastic rocks are shown in Figure 3. Drill hole core samples from central Eldorado Township (1971, Mespi Mines Ltd., Hole 1-71 and Hole 2-71) revealed several horizons of felsic-lithic tuff interlayered with intermediate volcanic flows. The magnetic susceptibilities of these drill core samples and those of the outcrops on the north-western part of Langmuir Township are low and in the range of 2 to 10×10^{-6} cgsu. Twenty-three samples were examined.

The 37 feldspar porphyry samples were obtained from Mespi Mines drill holes (1971, Hole 1-71, Hole 2-71) in central Eldorado Township (ACME property), an unknown drill hole in east-central Eldorado Township near the iron formation and drill holes from McWatters Gold Mines property in west-central Langmuir Township. In each case, the apparent thickness is not more than five feet (1.5 m) and the texture is distinctively porphyritic. Intermediate volcanic rocks such as andesite can also have a porphyritic texture, but if one compares the magnetic susceptibility

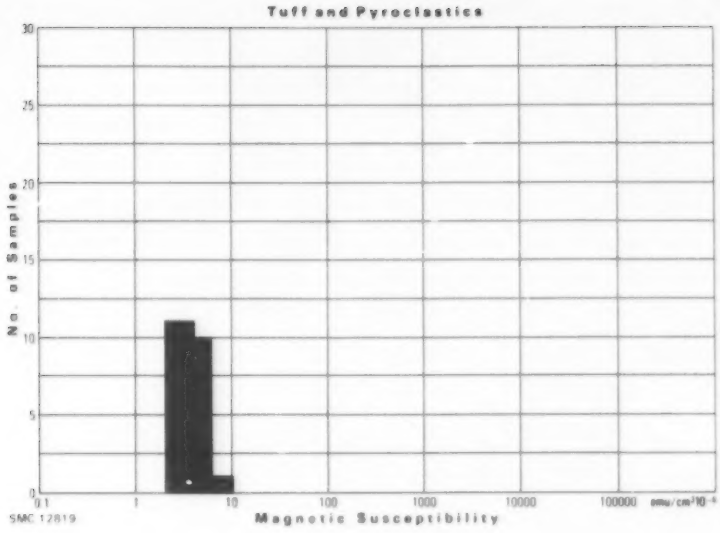

Figure 3–Magnetic susceptibility of felsic pyroclastic rocks.

of the samples on hand with that of intermediate volcanic rocks in the survey area, it appears more likely that this lithologic unit is an intrusive feldspar porphyry. The contact boundaries in the drill holes do not help very much in these cases. The range of magnetic susceptibility of the feldspar porphyry is shown in Figure 4 and extends from 1 to 100 $\times$ 10^{-6} cgsu. This is very similar to the range of the felsic intrusives in the area.

Figure 5 shows the magnetic susceptibility of felsic intrusives in the area. The 53 readings for felsic intrusives (trondhjemite and monzonite) were made with the in situ coil on outcrops, as there were no drill core samples available. The light grey, medium-grained trondhjemite at the Eldorado-Langmuir Township boundary contains only a trace of magnetite (Pyke 1970) whereas the monzonite in southern Langmuir Township contains 1 to 3 percent magnetite (Pyke 1970). The magnetic susceptibility range for felsic intrusives is 1.0 to 85 $\times$ 10^{-6} cgsu.

Twenty representative samples of mafic volcanic rocks from central and south-central Langmuir Township were chosen for magnetic susceptibility measurements. The results are presented in Figure 6. The samples are dark greenish grey, fine-grained, massive volcanic rocks which appear to be chloritized and carbonatized. Two drill core samples of porphyritic andesite are included. The magnetic susceptibility is unexpectedly low and ranges from 2 to 10 $\times$ 10^{-6} cgsu. Two samples of chlorite schist from southern Langmuir Township have susceptibility values from 30 to 32 $\times$ 10^{-6} cgsu and 34 to 36 $\times$ 10^{-6} cgsu. No samples of the contact-metamorphosed mafic volcanic rocks mentioned by Pyke (1970) were included in the susceptibility measurements. The low magnetic susceptibility of the mafic volcanic rocks may be caused by regional metamorphism and fine grain

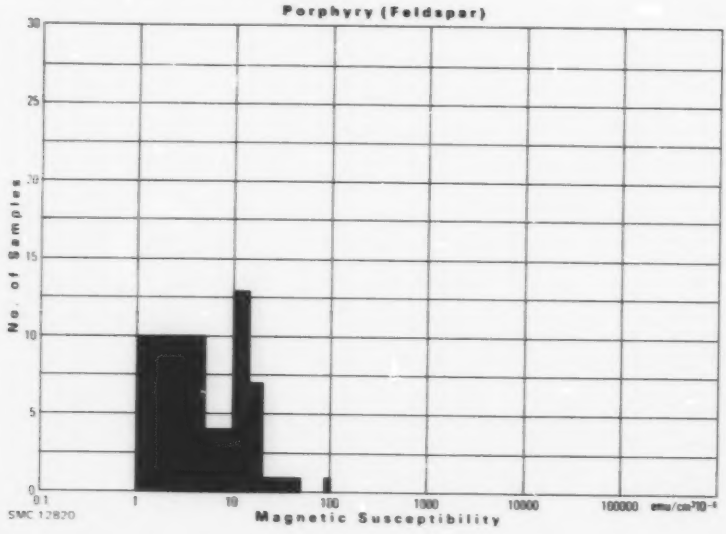

Figure 4–Magnetic susceptibility of feldspar porphyry.

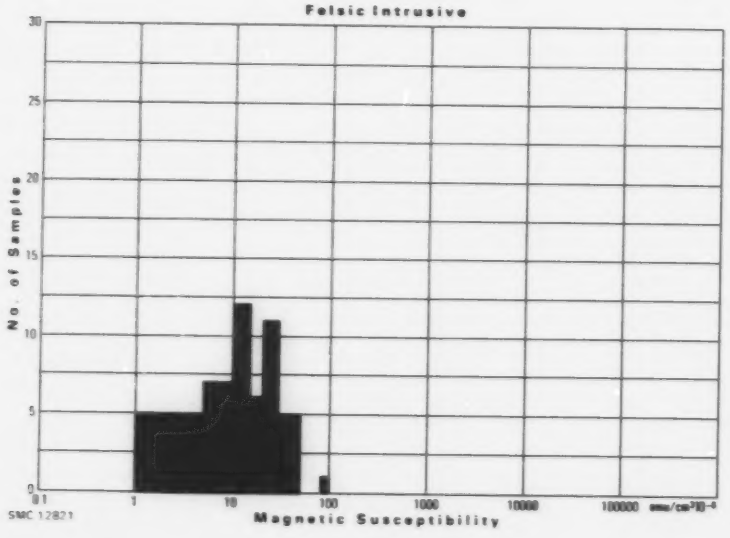

Figure 5–Magnetic susceptibility of felsic intrusives.

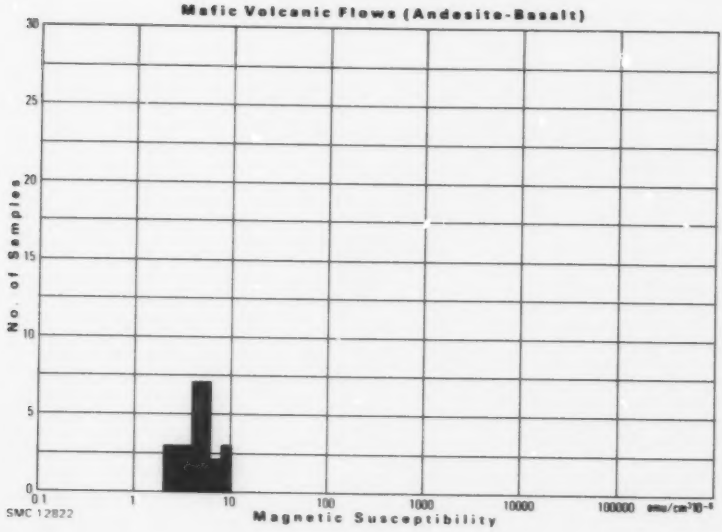

Figure 6–Magnetic susceptibility of mafic metavolcanics.

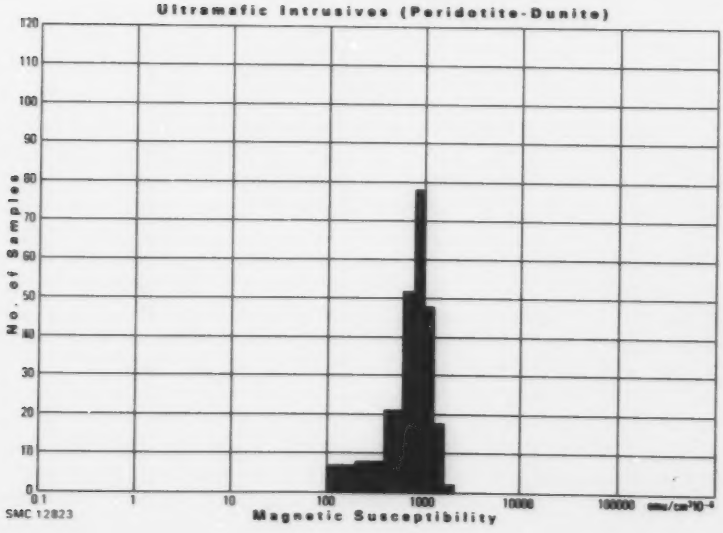

Figure 7–Magnetic susceptibility of ultramafic intrusives.

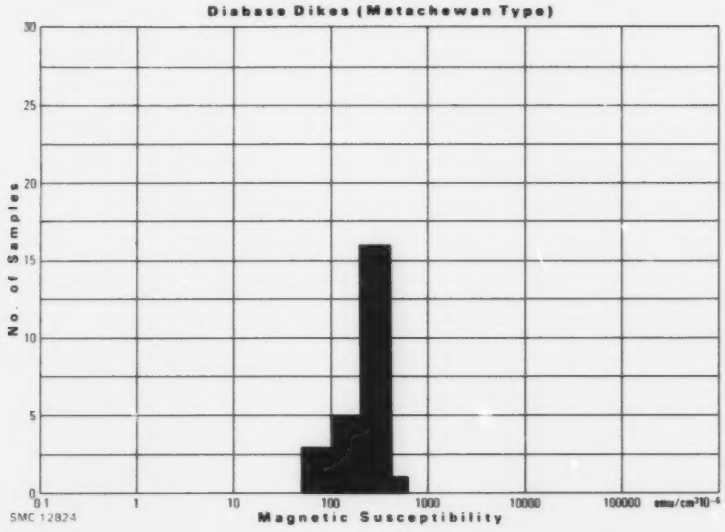

Figure 8–Magnetic susceptibility N-S diabase dike. (Matachewan type)

size. Chemical analyses should be helpful in finding an explanation for this phenomenon. The relationship between metamorphism and magnetic susceptibility in Precambrian mafic volcanic rocks requires further investigation.

The ultramafic rocks in the survey area are very important because of the associated nickel sulfide mineralization. The Noranda-Inco ore body is connected with them, and mineral exploration has been very active in their vicinity. Consequently, a large number of drill cores from the ultramafic rocks is available in many parts of the area. 259 magnetic susceptibility measurements have been made, two thirds of them on core samples, and the remainder with the in situ coil on outcrop. The range of the readings is from 100 to 2800×10^{-6} cgsu. Included in the sample population are some yellowish green, highly altered (serpentinized) rock specimens. Usually, the highly altered samples show relatively low magnetic susceptibility values around 1000×10^{-6} cgsu. Figure 7 shows the distribution of the values.

The magnetic susceptibilities of the diabase were measured on 12 northeast-trending and 25 north-trending dikes. According to Pyke (1970), the mineral compositions in the diabase dikes in Langmuir Township are similar. However, in the survey area the magnetic properties are quite different, as Figures 8 and 9 demonstrate. The susceptibility values of the north-trending diabase dikes range from 70 to 600×10^{-6} cgsu, whereas the readings for northeast-trending dikes are spread from 1 to 200×10^{-6} cgsu. The spread of readings for the northeast-trending diabase dikes may be explained by the degree of differentiation of the minerals composing them, which increases with the thickness of the dikes. In the considerably thicker northeast-trending dikes, the heavy minerals with high magnetic susceptibility are more concentrated near the contacts, and abundant

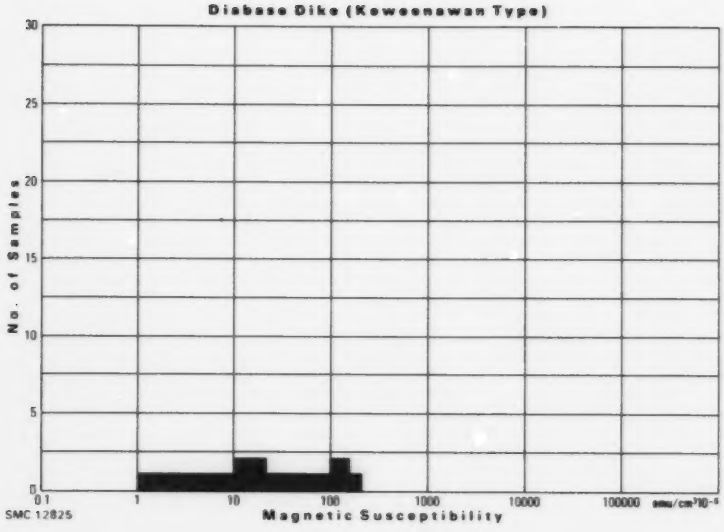

Figure 9–Magnetic susceptibility NE-SW diabase dike. (Keweenawan type)

plagioclase is found away from the contacts. According to Pyke (1970), the magnetite content varies from 1 to 8 percent in northeast-trending dikes and amounts to 4 to 6 percent in the north-trending diabase dikes.

Twenty-five readings were taken on the Cobalt Group conglomerate (see Figure 10) in the southwestern part of Langmuir Township. There were no drill core samples available, and all the readings were taken on outcrops with the in situ coil. The readings range from 1 to 20×10^{-6} cgsu for groundmass and most felsic pebbles; a few readings showed values of up to 1000×10^{-6} cgsu. These high readings were taken over dark grey fine-grained pebbles and dark brown rusty pebbles which may be iron formation. This is not unusual for polymictic conglomerates in this area.

Susceptibility readings on eight drill core samples and 12 outcrops of iron formation are shown in Figure 11. The drill core samples are from east-central Eldorado Township and north-central Langmuir Township. The values range from 300×10^{-6} cgsu to off scale on the Bison susceptibility meter (which means the reading is greater than $10{,}000 \times 10^{-6}$ cgsu).

The range of magnetic susceptibility of all bulk lithologic units are summarized in Table 1 and Figure 12.

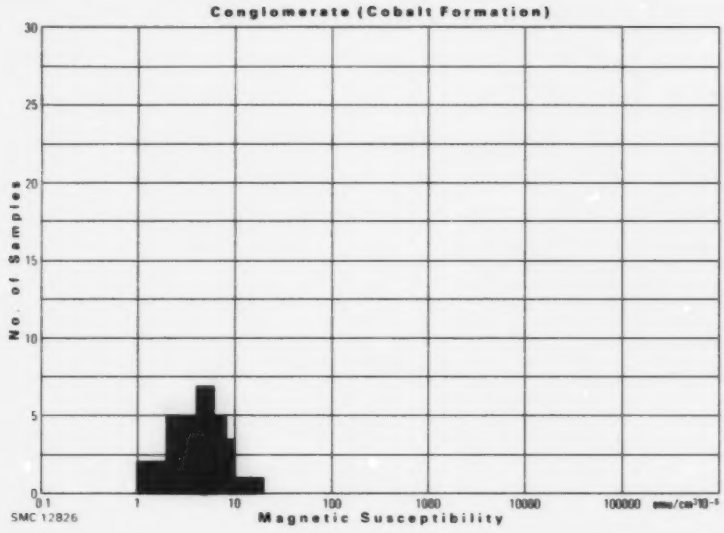

Figure 10–Magnetic susceptibility of Cobalt type conglomerate.

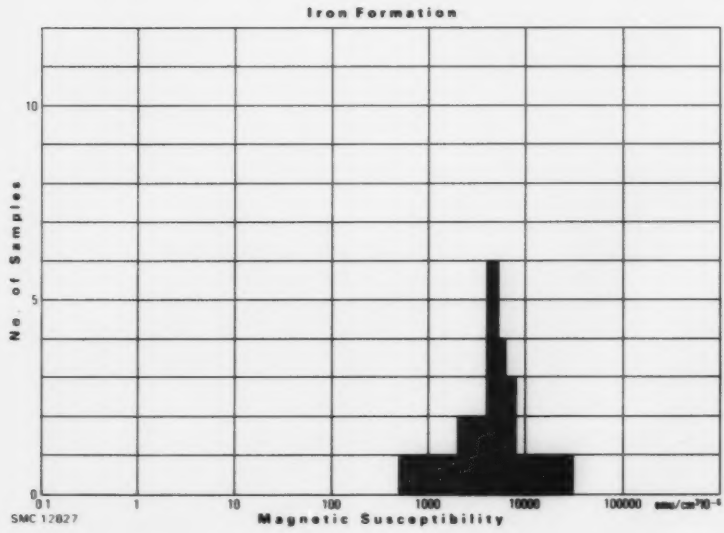

Figure 11–Magnetic susceptibility of iron formation.

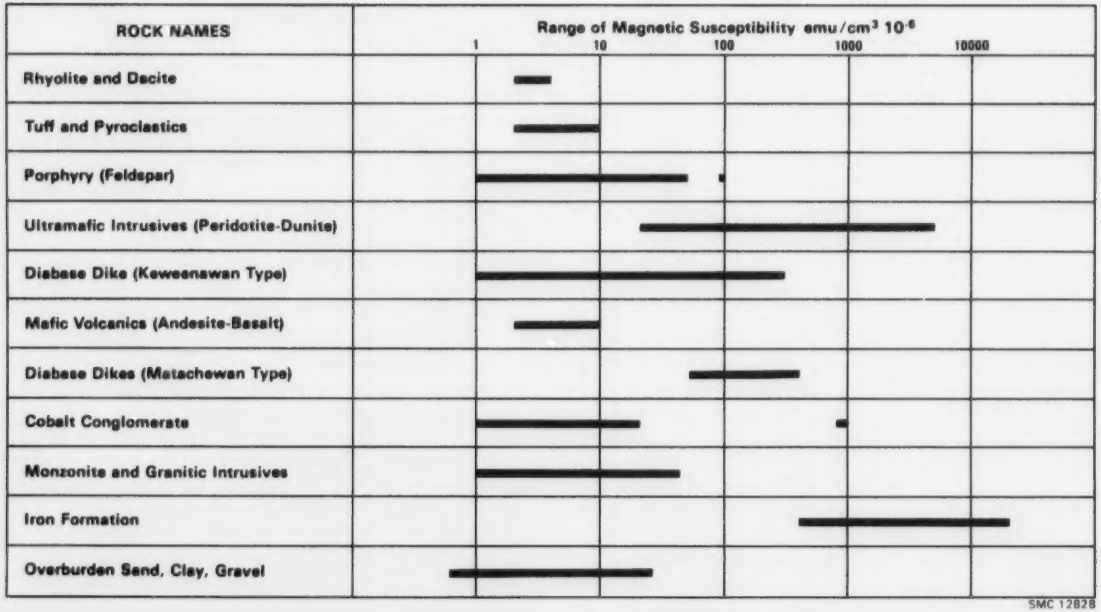

Figure 12–Range of magnetic susceptibility of each lithologic unit in the survey area.

Table 1 MAGNETIC SUSCEPTIBILITY OF ROCKS FROM LANGMUIR AND ELDORADO TOWNSHIPS

ROCK TYPE	NUMBER OF SAMPLES	RANGE OF SUSCEPTIBILITY $\times 10^{-6}$ cgsu	* MODE VALUE $\times 10^{-6}$ cgsu
Felsic Metavolcanics, Rhyolite and Dacite	27	2.0 – 6.0	3.5
Tuff and Pyroclastics	23	2.0 – 10.0	4.0
Feldspar Porphyry	37	1.0 – 100.0	13.0
Felsic Intrusives, Monzonite and Trondhjemite	53	1.0 – 85.0	13.0
Mafic Metavolcanics	20	2.0 – 10.0	5.0
Ultramafic Intrusives	259	100.0 – 2800	1000.0
Diabase Dike N-S Matachewan Type	25	70.0 – 600.0	350.0
Diabase Dike NE-SW Keweenawan Type	12	1.0 – 200	140.0
Cobalt Type Conglomerate	25	1.0 – 20	5.0
Iron Formation	20	300 – >10,000	5000.0
Overburden (sand, gravel & clay)	26	1.0 – 25	3.0

*Mode instead of mean value is given because of the logarithmic character of the susceptibility range.

Overburden Properties

During the survey it was observed that the magnetic field readings and the field gradient in areas of thick overburden decreased considerably. Therefore, it was decided to investigate the overburden effects on the magnetic anomalies and their interpretation. The thickness of overburden was estimated from drill hole data and vertical resistivity soundings. The magnetic susceptibility of the sand, gravel, and clay overburden was measured on samples taken throughout the Township.

OVERBURDEN THICKNESS

The assessment files were checked for drill hole data in the survey area, and the locations of the drill holes with the thicknesses of overburden are indicated in Figures 13 and 14, together with the thickness estimates resulting from resistivity data.

As will be illustrated in the interpretation, the overburden thickness can also be estimated from the magnetic interpretation of the anomalies, and the overburden contour maps in Figures 13 and 14 were cross-checked using the magnetic interpretation method.

Figure 13–Map of estimated overburden thickness of Eldorado Township. – drill hole data with direction of dip and calculated vertical thickness of overburden; – resistivity vertical sounding array location with thickness of overburden. Contour interval 50 feet.

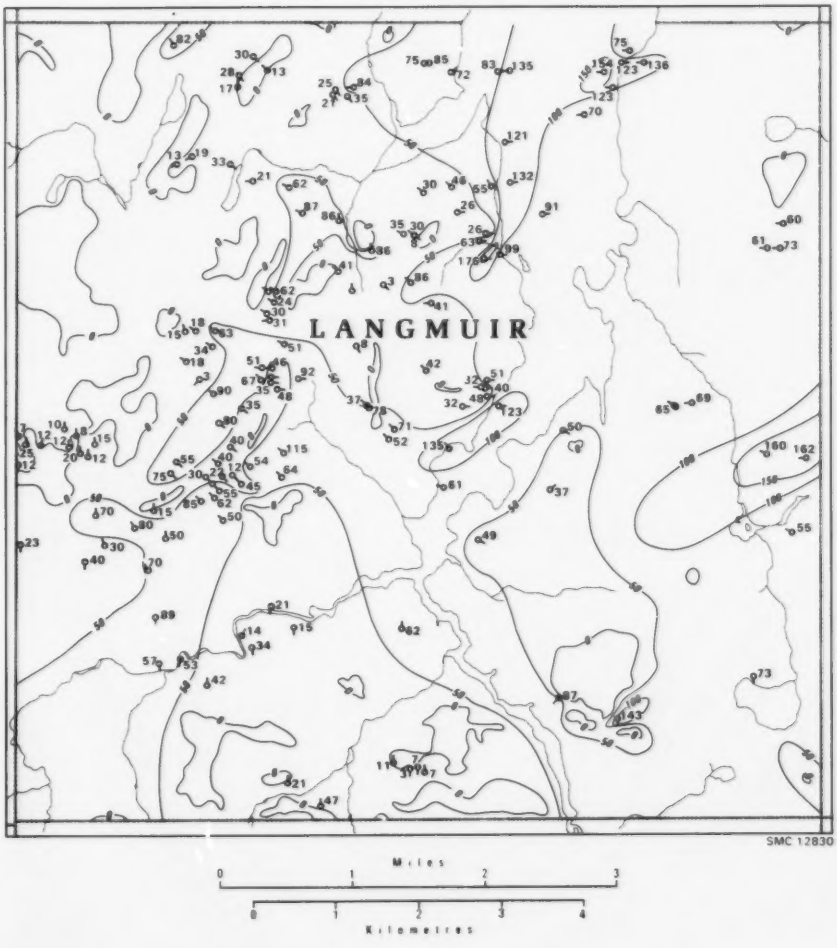

Figure 14–Map of estimated overburden thickness of Langmuir Township. – drill hole data with direction of dip and calculated vertical thickness of overburden. Contour interval 50 feet.

Eldorado Township has much less outcrop, and drill hole data are less plentiful than in Langmuir Township. Therefore, fifteen easily accessible locations in areas lacking outcrop were selected for vertical resistivity sounding. Normally, the seismic method would be the most suitable one for the determination of overburden thicknesses. However, there was no seismic unit available during the field season. Consequently, the resistivity method was employed. The instrument used was the Megger Earth Tester Model manufactured by Evershed and Vignoles Limited, England. At each location, the electrodes were expanded in the Wenner configuration with electrode spacings of 10, 25, 50, 75, 100, 125, and 150 feet (3, 7.5, 15, 23, 30.5, 38 and 46 m). The maximum electrode spacing is limited by the small current output of the generator, but the largest spacing of 150 feet (46 m) was sufficient for our purpose. The apparent resistivity values for all the locations were calculated, and it was found that five of the profiles produced meaningless values. These were not used. Ten resistivity vertical profile curves were drawn on bilogarithmic paper and are shown in Figures 15 to 24. The interpretation of resistivity data starts with the Bessel function even in the simplest two-layer case and becomes very complicated as the subsurface structure becomes multilayered. The mathematical aspects of the calculation of apparent resistivity and the derivation of the Mooney (Mooney and Wetzel 1957) curve for the horizontal two-layer case can be found in the literature (Stefanescu and Schlumberger 1930; Grant and West 1965). The Mooney curves used for the interpretation in this study are given in a master chart (Figure 25). This chart is prepared making the following assumptions: (a) the boundary between overburden and bedrock is a horizontal plane; (b) both layers are electrically isotropic and homogeneous. Consequently, in certain locations, the values determined from the chart may differ considerably from the true values.

The basic interpretation principle is curve matching. It is done in the following manner:

(a) The apparent resistivity values are plotted on logarithmic paper as in Figures 15 to 24.

(b) The curve thus obtained is compared with the master chart and the best fitting curve on this chart determined.

(c) The reflection factor K is then read off the theoretical curve found.

(d) The resistivity of the top layer is obtained by overlaying the master chart on the plotted curve, making the best fitting curve cover the plotted curve and noting where the "resistivity index" line on the master chart intersects the ordinate of the observed curve.

The resistivity index is the line on the master chart (Figure 25) representing $K=0$, which means that $\frac{\rho_a}{\rho_e} = 1$, and consequently, $\log \rho_a = \log \rho_e$. Superposition in this manner is valid because $\log \left(\frac{\rho_a}{\rho_e}\right) = \log \rho_a - \log \rho_e$ and $\log \left(\frac{a}{Z_1}\right) = \log a - \log Z_1$ and both $\log \rho_e$ and $\log Z_1$ are constant. Thus the sliding of the master chart vertically and horizontally is feasible, as a logarithmic scale is used.

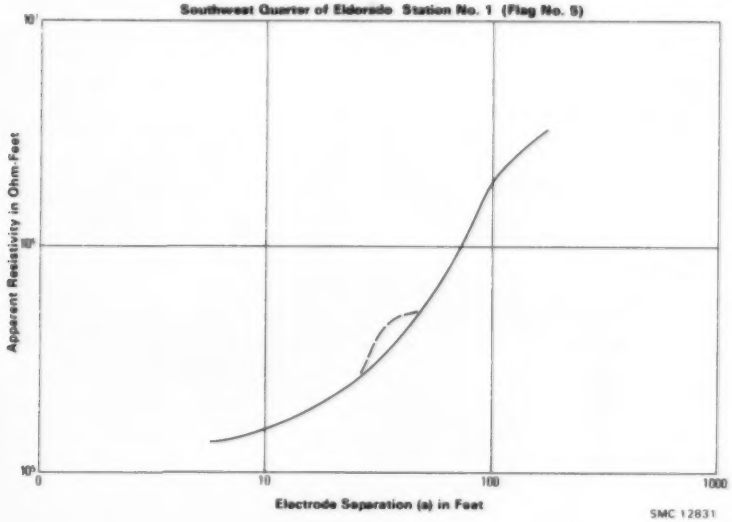

Figure 15–Resistivity vertical profile from location in Eldorado Township indicated in Figure 13.

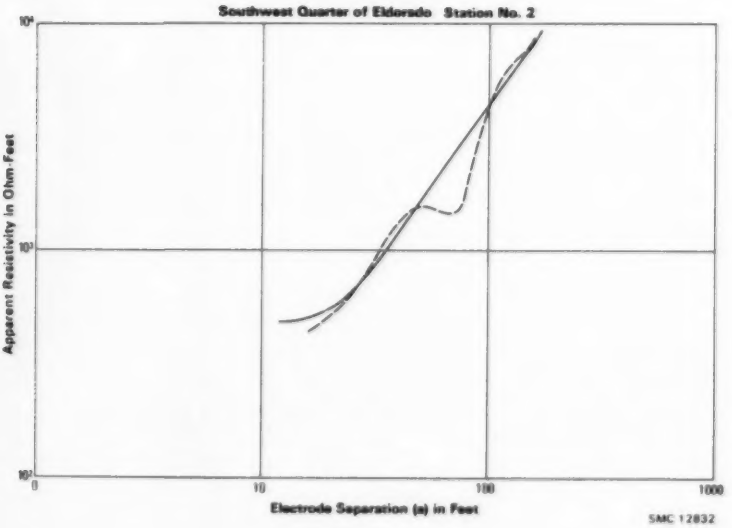

Figure 16–Resistivity vertical profile from location in Eldorado Township indicated in Figure 13.

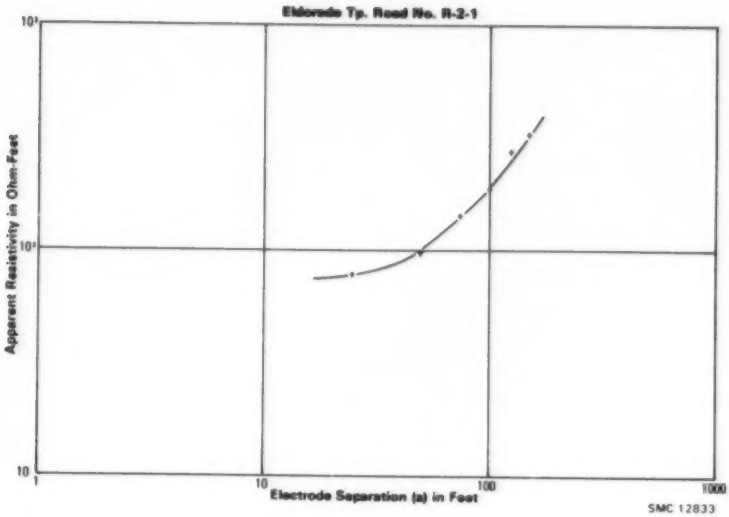

Figure 17–Resistivity vertical profile from location in Eldorado Township indicated in Figure 13.

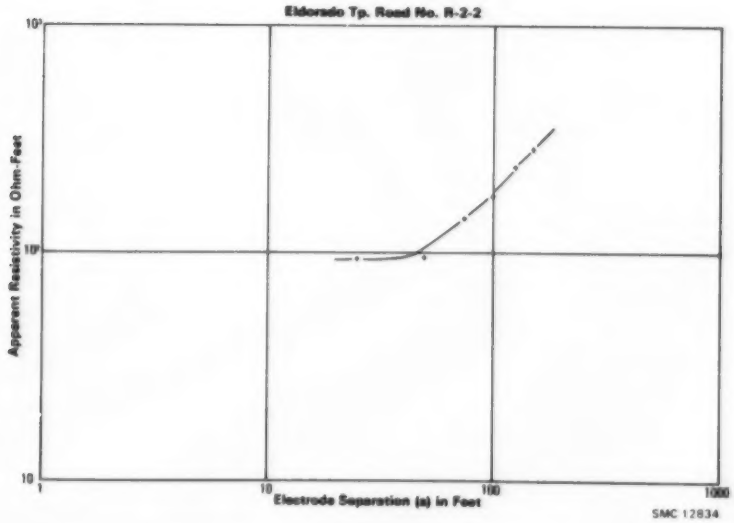

Figure 18–Resistivity vertical profile from location in Eldorado Township indicated in Figure 13.

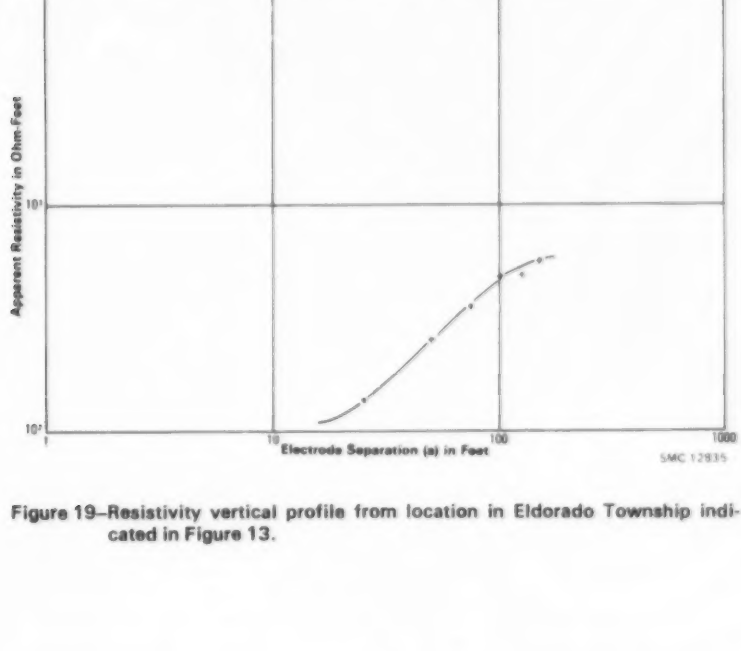

Figure 19–Resistivity vertical profile from location in Eldorado Township indicated in Figure 13.

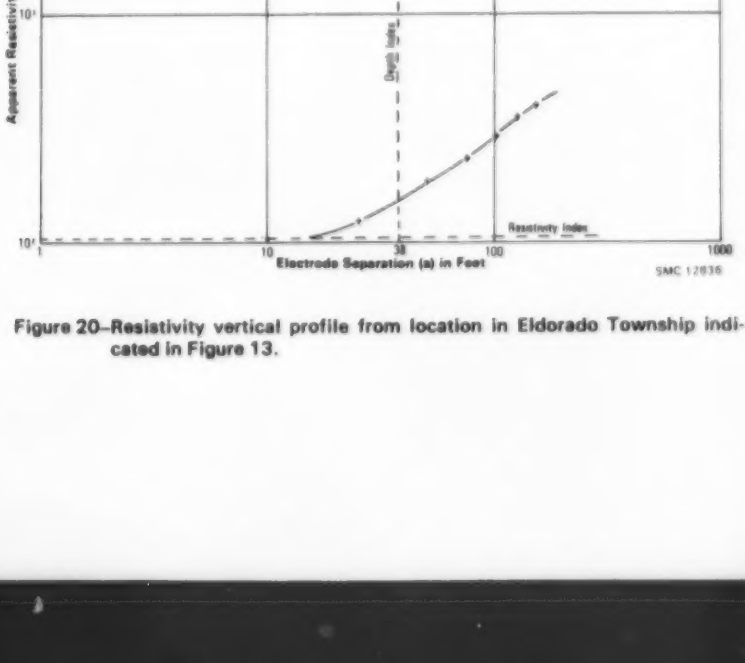

Figure 20–Resistivity vertical profile from location in Eldorado Township indicated in Figure 13.

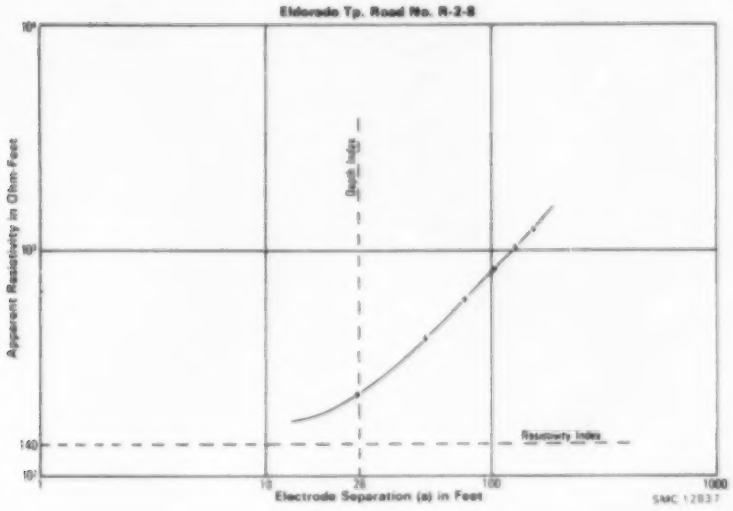

Figure 21–Resistivity vertical profile from location in Eldorado Township indicated in Figure 13.

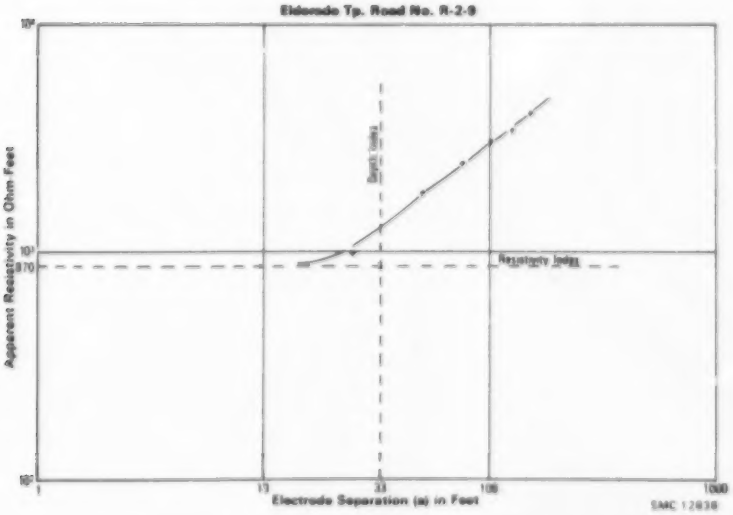

Figure 22–Resistivity vertical profile from location in Eldorado Township indicated in Figure 13.

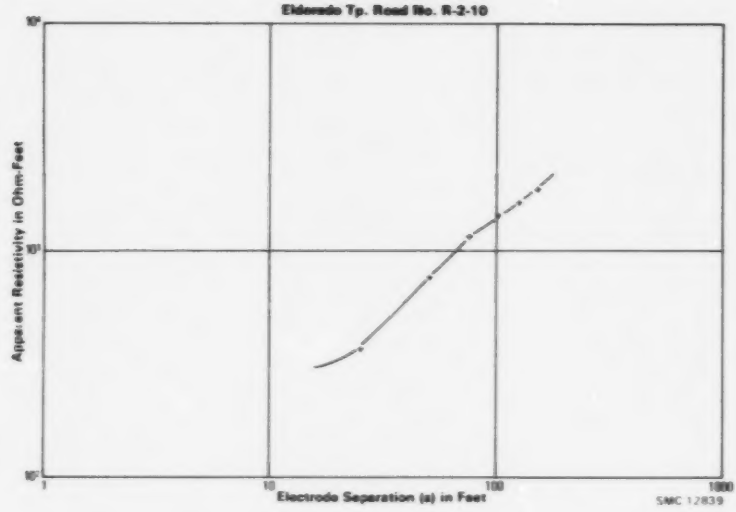

Figure 23–Resistivity vertical profile from location in Eldorado Township indicated in Figure 13.

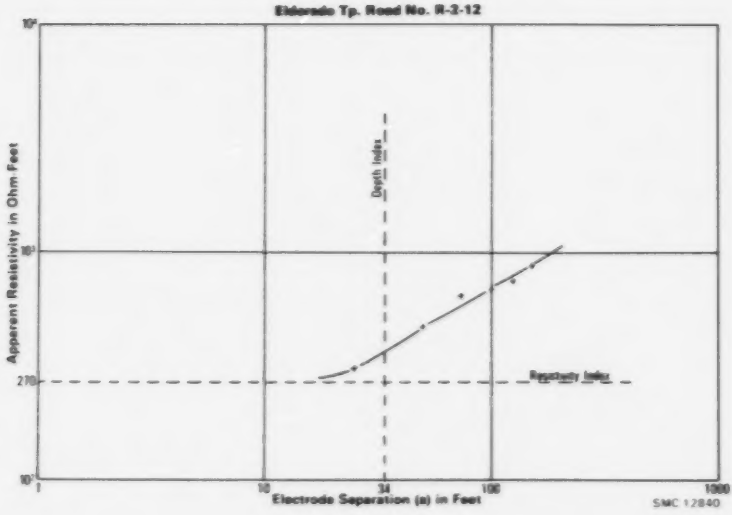

Figure 24–Resistivity vertical profiles obtained from locations in Eldorado Township given in Figure 13. For the profiles the curves that fit the horizontal two-layer model well, the resistivity index and depth index are also shown.

(e) The depth Z_1 of the overburden is obtained by noting where the vertical "depth index" line on the master chart (Figure 25) intersects the abscissa on the observed curve.

(f) The resistivity ρ_1 of the bedrock is determined directly from the relationship: $\rho_1 = \frac{1+K}{1-K}\rho_a$.

The results of interpretation are tabulated in Table 2. For the profiles with well matching curves the "resistivity index" and the "depth index" are shown on the figures. For the remainder, only the estimated resistivity and depth values are given in Table 2.

The overburden thickness in Eldorado Township varies generally between zero and 50 feet (15 m). In a few places, i.e. in the northwest corner, the north-central area and the southeast corner, it is greater and exceeds 100 feet (30 m) in the two first-named locations (Figure 13).

In Langmuir Township, the bedrock topography varies greatly in the eastern half. In the western half, the overburden thickness ranges from zero to 50 feet (15 m) in most areas, and numerous outcrops are present. Even around the Forks River area where there are few outcrops, the overburden is less than 50 feet (15 m) thick except near the western township boundary. In the eastern half of the township along Carman Bay and Night Hawk River, the depth to bedrock increases to 100 feet (30 m) or more in most parts where there is no outcrop. Even near outcrop the relief seems to change abruptly, as shown by one drill hole near an outcrop in the southeastern part of the township where the depth to bedrock is 143 feet (43.6 m). The maximum depth, 162 feet (49.4 m), occurs in the east-central part of the township.

The resistivity of the overburden in the area generally ranges from about 1.0 to 8.7×10^2 ohm-feet (350 to 3070 ohm-m) except at station No. 1 (Figure 15) which has resistivity of 1.55×10^5 ohm-feet (54.74×10^5 ohm-m). This station is located on a high, well drained sand and gravel hill, and the high resistivity value probably results from the dry character of the overburden.

MAGNETIC SUSCEPTIBILITY OF OVERBURDEN

The overburden in the survey area consists of sand, clay, and gravel; relative percentages vary considerably depending on the locations. Throughout the survey area, 52 representative samples for magnetic susceptibility measurements were taken from locations with thick overburden. However, the samples from the swampy areas contained too much organic material and were not suitable for this purpose. The measurements were made on 26 samples with a Scintrex SM-4 sample container and a Bison 3101A susceptibility meter calibrated for this container. The results are shown in Figure 26. The susceptibility range is from about 1 to about 25×10^{-6} cgsu. Because of the grain size effect, the sand or sand and gravel samples show higher values than the more clay-rich samples. Two samples with susceptibilities greater than 10×10^{-6} cgsu are from the southwestern part of Langmuir Township and are believed to contain more magnetite grains. The mode value of susceptibility for overburden is 3.0×10^{-6} cgsu and as seen in Table

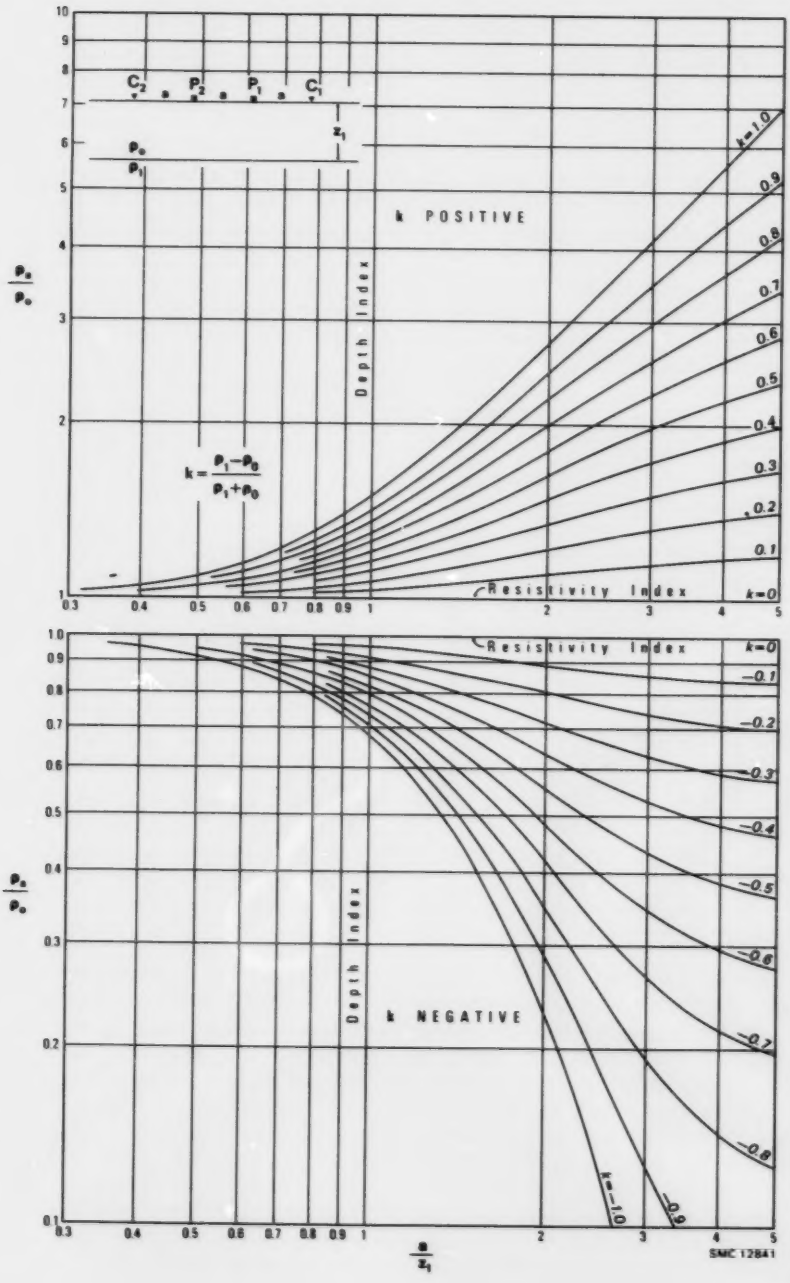

Figure 25–Mooney curves for the horizontal two layer case. (ρ_0 – resistivity of overburden, ρ_1 – resistivity of bedrock, a – electrode spacing, Z_1 – thickness of overburden, K – reflection factor). After Van Nostrand and Cook, 1966, p. 91.

Table 2 RESULTS OF THE VERTICAL RESISTIVITY SOUNDINGS, ELDORADO TOWNSHIP

Station No.	$K = \frac{\rho_1 - \rho_0}{\rho_1 + \rho_0}$	Overburden resistivity (Ohm-feet)	Bedrock resistivity (Ohm-feet)	Overburden thickness (feet) [m]
No. 1 (Fig. 15)	~−0.85	~1.55×10^5	1.26×10^4	~28 [8.5]
No. 2 (Fig. 16)		NO CURVE FITTING		
No. R-2-1 (Fig. 17)	~−0.70	1.5×10^2	~2.65×10	~70 [21]
No. R-2-2 (Fig. 18)		NO CURVE FITTING		
No. R-2-3 (Fig. 19)	~−0.65	9.0×10	~5.7×10	~22 [7]
No. R-2-7 (Fig. 20)	+0.8	1.0×10^2	9.0×10^2	38 [11.6]
No. R-2-8 (Fig. 21)	+0.98	1.4×10^2	1.98×10^4	26 [7.9]
No. R-2-9 (Fig. 22)	+0.9	8.7×10^2	1.65×10^4	33 [10]
No. R-2-10 (Fig. 23)		NO CURVE FITTING		
No. R-2-12 (Fig. 24)	+0.72	2.7×10^2	1.65×10^2	34 [10.4]

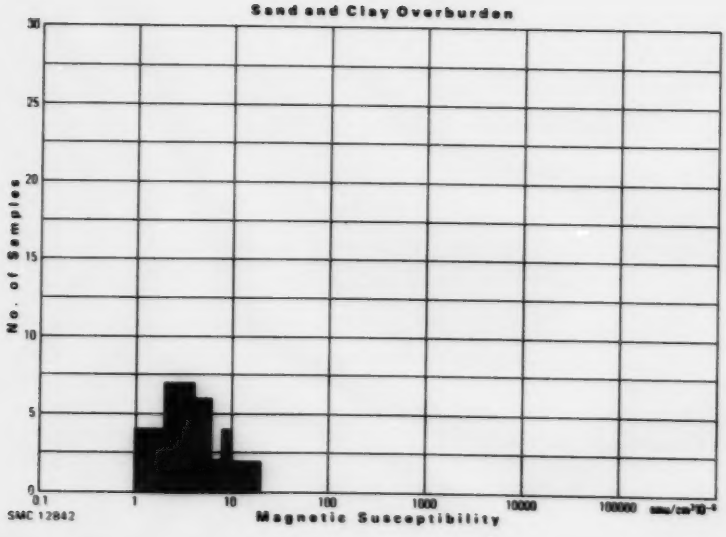

Figure 26–Magnetic susceptibility of overburden material in Eldorado and Langmuir Townships (26 samples).

1, is very close to the modes of the felsic metavolcanic, mafic metavolcanic, and pyroclastic rocks.

From this observation, it is concluded that unless there is an anomalous feature developed by a particular geometrical configuration, lithologic units within these three rock types and overburden cannot be distinguished by the induced magnetic field intensities only. A thick layer of overburden and a similarly shaped metavolcanic complex in the survey area could produce the same magnetic response pattern.

Interpretation

INTRODUCTION

The total magnetic induction B of a material, caused by an external magnetic field, is given by the expression:

$$\vec{B} = \mu_0(\vec{H_e} + 4\pi\vec{M}) \tag{1}$$

where, μ_0 = magnetic permeability of free space.
H_e = external magnetic field (in our case Earth's magnetic field at surface).
M = Magnetization of material.

And in many instances we can write:

$$\vec{M} = k\vec{H_e} \tag{2}$$

where, k = magnetic susceptibility of the material.

Then the total induced magnetic field is:

$$\begin{aligned}\vec{B} &= \vec{B_r} + \vec{B_\phi} + \vec{B_\theta} \\ &= H_e(1 + 4\pi k)\end{aligned} \tag{3}$$

where, B_r = vertical component, B_ϕ east-west component,
B_θ north-south component of magnetic induction.

Because $\mu_0 = 1$ in cgs units.
Now from the relations,

$$\vec{H} = \mu B \tag{4}$$

$$H_r = |\vec{H}| \cos(\text{angle of inclination}) \tag{5}$$

where, H = total magnetic field,
H_r = vertical magnetic field.

If the earth's field H_e is uniform, as it almost is in the relatively small survey area, then the H_r values measured in the field are linearly dependent on the magnetic susceptibility of the lithologic units in the survey area.

From this simple fact, if we know the representative bulk magnitude of the magnetic susceptibility of the lithologic units, the geological interpretation of the magnetic anomaly map should be easy. However, in reality, it is very complicated. The magnetic susceptibility k in equation (3) is a scalar quantity in an isotropic and homogeneous material, but rock formations are generally not isotropic or homogeneous. The anisotropy of magnetic susceptibility and remanent magnetism in most lithologic units changes the direction of the induced magnetic field vector. The interactions of the earth's magnetic field vector, and the induced magnetic field vectors from the magnetically anisotropic, inhomogeneous lithologic units make the detailed interpretation of magnetic anomalies very difficult, even with the mathematical inversion scheme aided by a computer.

Another difficulty in attempting direct geological mapping by detailed magnetic surveying becomes apparent from Table 1. In the survey area, the felsic metavolcanic, mafic metavolcanic and pyroclastic rocks, and the sand and gravel overburden have very narrow magnetic susceptibility ranges, 2.0 to 36.0 $\times 10^{-6}$ cgsu, without any particular susceptibility contrast in the modal values. The only lithological units which can be mapped by magnetic methods are ultramafic rocks, diabase dikes, and iron formation. The felsic intrusions show only a slightly higher modal value of magnetic susceptibility of 13 $\times 10^{-6}$ cgsu than the metavolcanic rocks.

Another point to remember in a magnetic interpretation is that the magnetic property of rocks depends, mainly, upon the trace mineral content (e.g. magnetite) rather than on the bulk constituents.

The main rock units then, that can be outlined in the interpretation of the magnetic anomalies, are the ultramafic masses, the diabase dikes and/or sills, and the iron formation. From the magnetic susceptibility contrast between these rocks and the backgrounds (e.g. felsic intrusives and metavolcanics), and applying anomaly model curves, an attempt is made to understand the subsurface structural geology of the survey area.

For a complete understanding of the geology of the area, readers are advised to consult Pyke's (1970, 1972) reports in conjunction with this study.

REGIONAL INTERPRETATION

The magnetic anomaly in the survey area is part of a regional, roughly elliptic anomaly visible in Figure 28. This interesting magnetic anomaly is centered in the southern part of Shaw Township. About a third of it covers Eldorado and Langmuir Townships. It has not been interpreted before in formal reports, and an attempt is made here to understand the regional structure of the Timmins-South Porcupine mining area. Since it would be foolish to try to interpret the regional structure entirely from a magnetic map, a gravity map of the area (Gibb *et al* 1969) is included (Figure 27).

On the aeromagnetic (Figure 28) and gravity maps (Figure 27), one can observe a coincidence of the −550 milligal Bouguer anomaly contour and the magnetic high contours in shape, location and approximate scale.

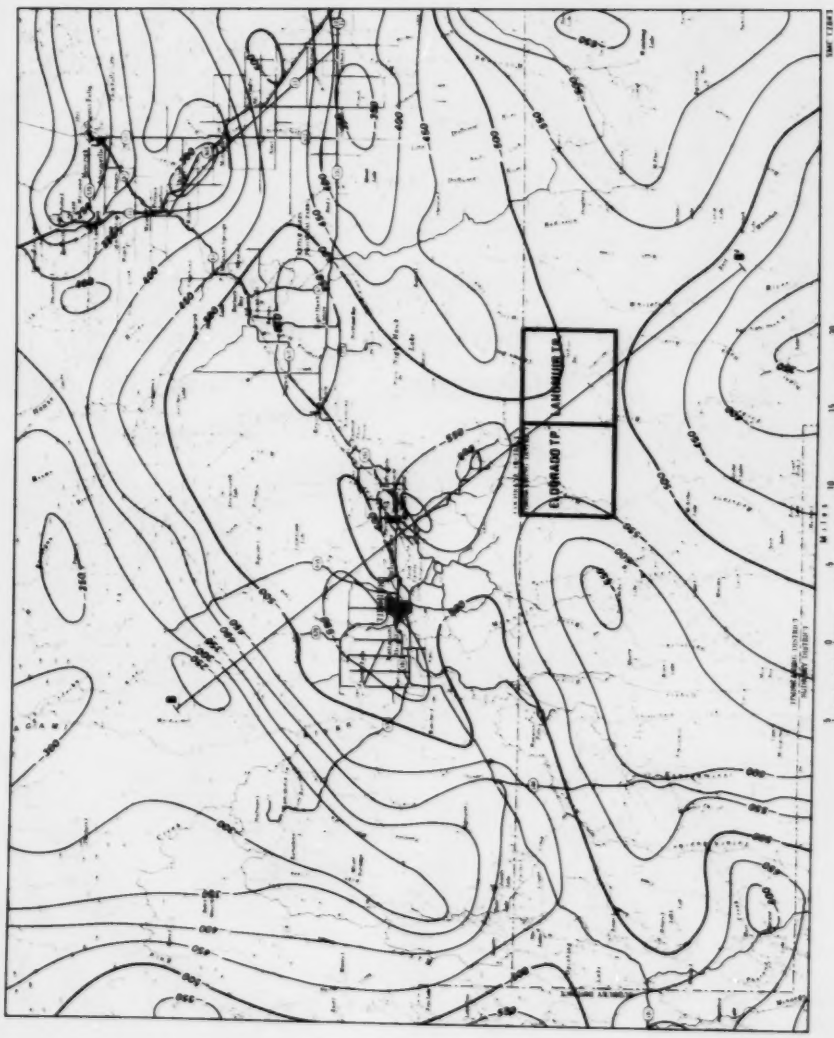

Figure 27–Bouguer anomaly map of Timmins Area (Dept. of Energy, Mines and Resources Gravity Map Series No. 58). Scale 1:500,000. Contour interval 50 milligals. The survey area is shown. B – B' location of gravity profile.

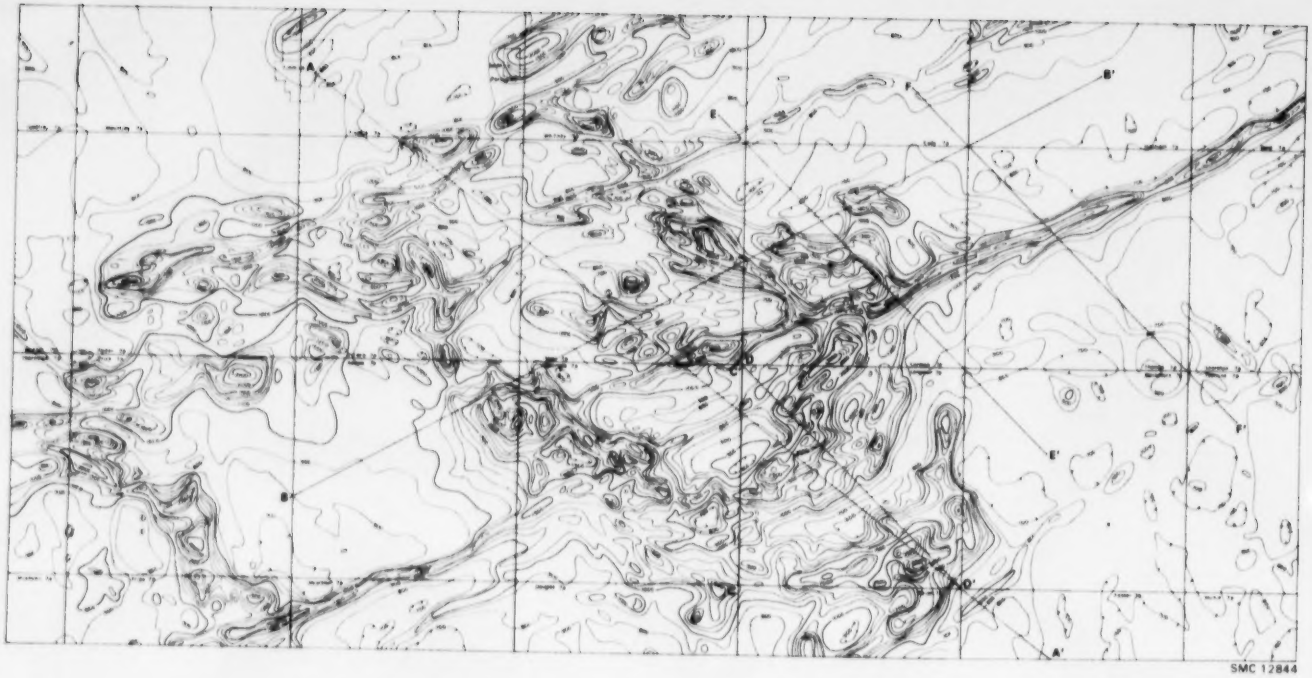

Figure 28–Aeromagnetic maps of Timmins–South Porcupine Area (Map No's 293G and 294G published by Ontario Dept. of Mines and Geological Survey of Canada, 1970). The lines indicate the profile lines.

GRAVITY MODEL

To obtain more quantitative information from the gravity anomaly map, a profile was constructed across the general area including Eldorado and Langmuir Townships, and a model anomaly calculation was done. The profile line was arranged in NW-SE direction, approximately at right angles to the Porcupine-Destor Fault[1] and to the northeast trending diabase dikes. The profile shows a clear indication of mass deficiency southeast of the Porcupine-Destor Fault and northwest of the diabase dikes. Ferguson (1968) indicated that the apparent displacement of the Porcupine-Destor Fault might be as much as 5,000 feet (1500 m), based on stratigraphic relations, although structural evidence of vertical movement is lacking.

Gibb *et al.* (1969, p.21) suggests that the metavolcanic and metasedimentary pile in the Timmins-South Porcupine area extends to a depth of 6 kilometres (~20,000 ft) assuming that the metavolcanic-metasedimentary sequences are underlain by granitic rocks.

The structural model shown with the gravity profile in Figure 29 is based on the stratigraphic observations of Ferguson (1968), the Bouguer gravity data and the granitic floor theory of Gibb *et al.* (1969).

The rock density data used in the calculation of the gravity model (Figure 29) were obtained by the author and assistants during the 1971 field season for a planned detailed gravity survey in the South Porcupine area. These density data, together with data given by Gibb *et al.* (1969) are shown in Table 3. They will be discussed in more detail later in this report.

The two-dimensional model was obtained by a best curve fitting model determined by the numerical iteration method. The calculations, with a density contrast of $-0.14\ g/cm^3$, were done by computer. The range of vertical displacement of the faults in question is from 1,000 to 4,600 feet (300 to 1400 m), and the depth range considered for the uplifted centre block of the model is from 1,000 to 41,000 feet (300 to 12,500 m) from surface. The hypothetical geological model is discussed below.

GEOLOGICAL INTERPRETATION OF THE MODEL

From the regional distribution of granitic bodies and the Bouguer anomaly pattern, the uplifted granitic body in the model may be a continuation of the Kenogamissi Lake area granitic mass with a strike of about N50°E. The exact throw of the fault system in the model cannot be determined. The fact that Timiskaming type sediments occur on the south side of the Porcupine-Destor Fault suggests that the Porcupine-Destor Fault is one of the systems of parallel faults with drag folding on both sides.

Another possible interpretation of the model is that the actual throw on the Porcupine-Destor Fault is small and that the fault is located on the southern limb of a large synclinal structure through Timmins and South Porcupine, and on the northern limb of a large anticlinal structure through Deloro, Shaw, and Adams Townships. More detailed geophysical and geological work is required

[1]Named Destor-Porcupine Fault in Pyke (1970).

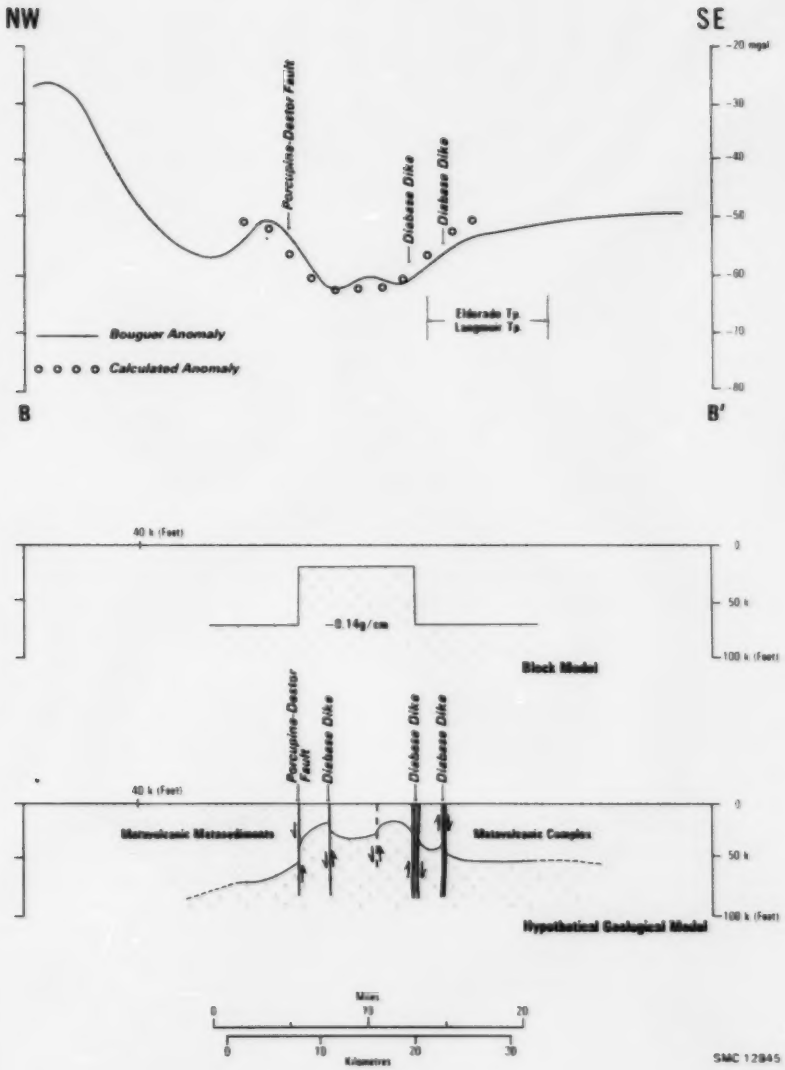

Figure 29–Bouguer anomaly profile with a simple geologic model interpretation. (The cross section runs along the line B – B' shown in Figure 27.)

Table 3 DENSITY OF ROCKS IN SOUTH PORCUPINE AREA. (THE DATA WITH ** WERE OBTAINED BY GIBB *et al.* (1969); ALL OTHERS IN LANGMUIR-ELDORADO-SHAW AND DELORO TOWNSHIPS BY THE AUTHOR.

ROCK TYPE	NO. OF SAMPLES	DENSITY RANGE (g/cm³)	MEAN DENSITY (g/cm³)	OBSERVER
Felsic volcanic and pyroclastic rocks	5	2.70–2.85	2.80	W. Moon
(Acid volcanic rocks)	5	2.64–2.72	2.68	**
Intermediate mafic volcanic rocks	29	2.65–3.00	2.83	W. Moon
Mafic to ultramafic metavolcanics	20	2.78–3.11	2.94	**
Peridotite Serpentinized	49	2.45–3.00	2.70	W. Moon
Diabase dikes	5	2.80–3.07	2.94	W. Moon
Iron Formation	5	2.92–4.34	3.47	W. Moon
(Granite)	68	2.54–2.74	2.65	**
(Granodiorite)	29	2.61–2.84	2.72	**
(Diorite and quartz diorite)	27	2.63–2.90	2.75	**

before further elaboration of this model can be undertaken. However, it is hoped that this crude model will further the understanding of the regional structural geology. A detailed gravity survey along the Porcupine-Destor Fault is being conducted by R. S. Middleton, and its results may lead to a clarification.

MAGNETIC INTERPRETATION OF THE MODEL

The total field magnetic profile (Figure 28 and Figure 30) along the gravity profile line (Figure 29) indicates a higher background field intensity across the uplifted portion of the model. In general, the magnetic susceptibility of granitic rocks is higher than that of metavolcanic-metasedimentary sequences (D. H. Hall 1968), and as shown in Table 1, the modal value of the felsic intrusive rocks of the survey area is slightly higher than that of the metavolcanic and metasedimentary rocks. If the metavolcanic-metasedimentary sequence south of the Destor-Porcupine Fault is underlain by a granitic mass with the same magnetic properties as the felsic intrusive rocks in the survey area, the higher background level may be explained by this magnetic susceptibility contrast. However, it is also possible that small, short wavelength, high amplitude magnetic anomalies (e.g. iron formation, ultramafic dikes, etc.) at shallow depth produce a higher background level by overlap and compounding of field intensities. Figure 30 shows the magnetic profiles across the structure. The magnetic anomalies over the trondhjemite intrusion in Eldorado-Langmuir Townships and the Night Hawk River valley will be investigated later in detail.

With reference to Ferguson (1968) and Pyke (1970), and the hypothetical geological model (Figure 29) a generalized Table of lithologic units and corresponding geological events is presented (Table 4).

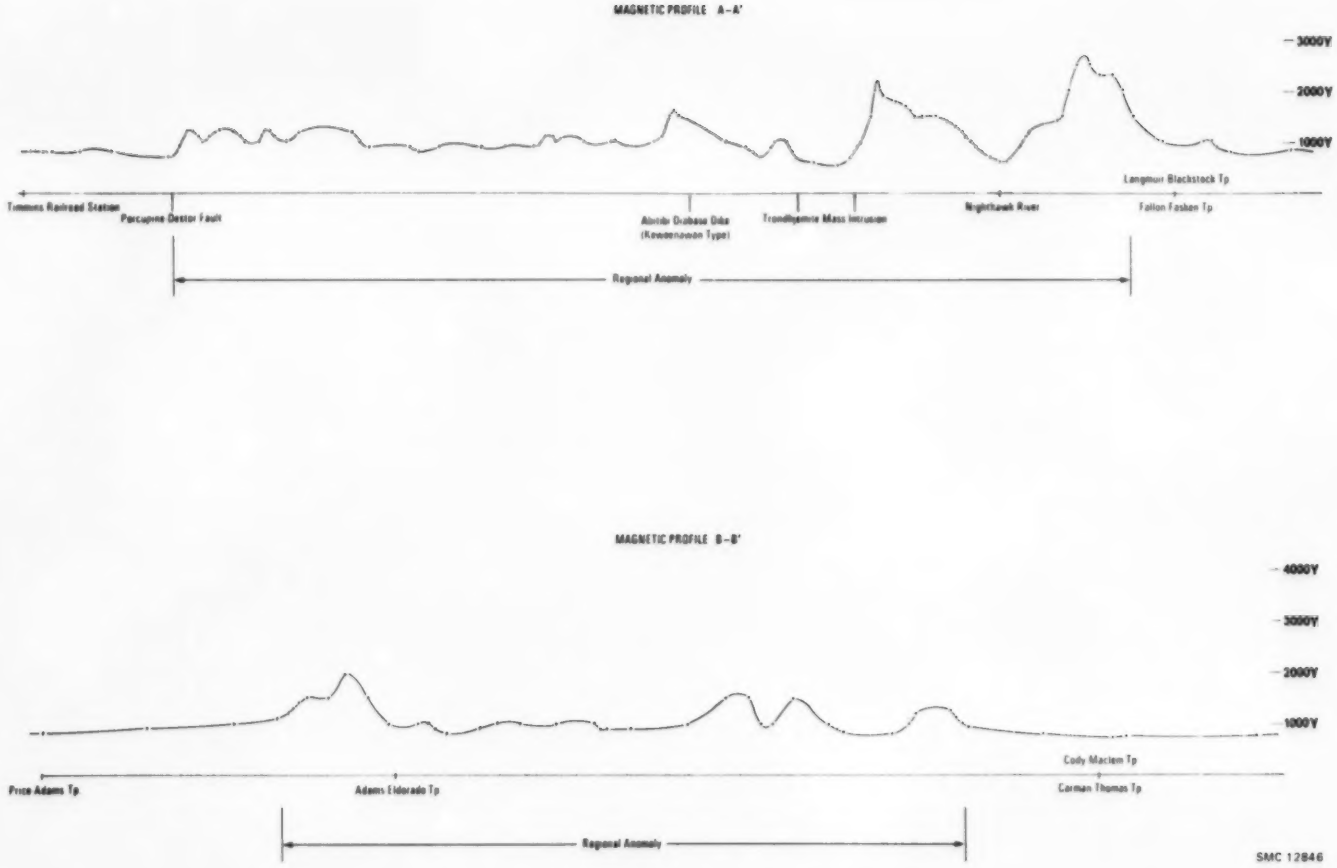

Figure 30–Total field magnetic profiles. The profile lines are shown in Figure 28.

Table 4 TABLE OF LITHOLOGIC UNITS AND GEOLOGICAL EVENTS

GEOLOGICAL TIME		LITHOLOGIC UNITS	GEOLOGICAL EVENTS
CENOZOIC	RECENT	Swamp and Stream deposits.	
	PLEISTOCENE	Till, clay, sand, gravel	
	.....TIME BREAK.....		Unconformity
PRECAMBRIAN	(LATE TO MIDDLE PRECAMBRIAN)		Burrows-Benedict Fault, Porcupine-Destor Fault, and regional scale faults without diabase injection.
	.....TIME BREAK.....		
		Late mafic intrusive diabase dikes.	Intrusion of diabase along faults and fractures.
		Cobalt group conglomerate and argillite	Faulting
	.....TIME BREAK.....		Unconformity
		Felsic intrusive rocks trondhjemite, granodiorite, feldspar porphyry, monzonite, etc.	Intrusions
	EARLY PRECAMBRIAN	Ultramafic intrusive rocks, serpentinized diorite, serpentinized peridotite, gabbro, etc.	Intrusions
		Timiskaming type sedimentation	
	.....TIME BREAK.....		Unconformity
		Keewatin type metavolcanics and metasediments.	

In the above table, the Destor-Porcupine Fault, the Burrows-Benedict Fault (see Ferguson 1968) and other regional faults are interpreted as formed after the intrusion of the diabase dikes. If these faults predated the diabase intrusion, it would seem likely that diabase would have been emplaced along these fault zones. In the South Porcupine area, there is no evidence for diabase occurrences of this kind.

In conclusion, the elliptic (or parallelogram shaped) distribution of the ultramafic rocks, the magnetic anomaly shown in Figure 28 and the Bouguer anomaly in Figure 27 may be interpreted as a volcanic cone type structure later fractured by repeated fault movements. The low gravity anomaly at the center of the structure and the occurrences of trondhjemite, which is closely associated with Precambrian volcanic structure, in Eldorado and Langmuir Townships support this hypothesis. However, a more exact picture of the elliptic structure during the Precambrian time may be determined by further study of the geochemical and geological parameters associated with Precambrian volcanism.

DETAILED MAGNETIC INTERPRETATION

In Langmuir Township, the general trend of the positive magnetic anomalies swings from about N70°E in the south to about N50°E in the northwest. In the eastern quarter of the township, they strike approximately north. The background vertical magnetic field intensity of the area is about +1000 γ. The felsic and mafic metavolcanic rocks can not be distinguished from each other due to similar magnetization intensities. As seen from the profiles in Figure 31, magnetic anomalies associated with the diabase dikes rise only slightly above the regional background level. As seen on the map, the two northeast-striking diabase dikes in the northwest corner of Langmuir Township show clear linear anomalies with strikes of N50°E - N60°E, and with a recognizable width. The north-south diabase dikes (Matachewan type) generally show weaker vertical field strength. A few of them can be traced, but generally, they are overshadowed by the adjacent anomalies of ultramafic intrusions or blurred by overburden. Only surface geological mapping can tie in the Matachewan type diabase dikes in the survey area.

The iron formations produce a very high vertical magnetic field on outcrops, but the anomalies are narrow, small and discontinuous. One iron formation outcrop in west-central Langmuir Township gives a reading up to +10,000γ. In general, the anomalies due to iron formation have the following characteristics: (1) narrowness in width, (2) discontinuity in strike, (3) shallowness in depth and (4) very short wavelength. If the iron formation is not associated closely with ultramafic rocks, it can be used as a key lithologic unit in the structural interpretation. However, the iron formation anomalies in the survey area are very erratic, and it is not recommended to use it as the sole structural criterion in magnetic geological mapping.

The ultramafic rocks in the survey area consist mainly of serpentinized peridotite and dunite. Small outcrops of gabbroic and dioritic rocks were mapped near the Langmuir-Eldorado boundary by Pyke (1970). The ultramafic rocks have high magnetic susceptibility as shown in Table 1 and can be outlined by the +2000 γ contour. The +3000 γ contour may, in a qualitative way, represent the actual

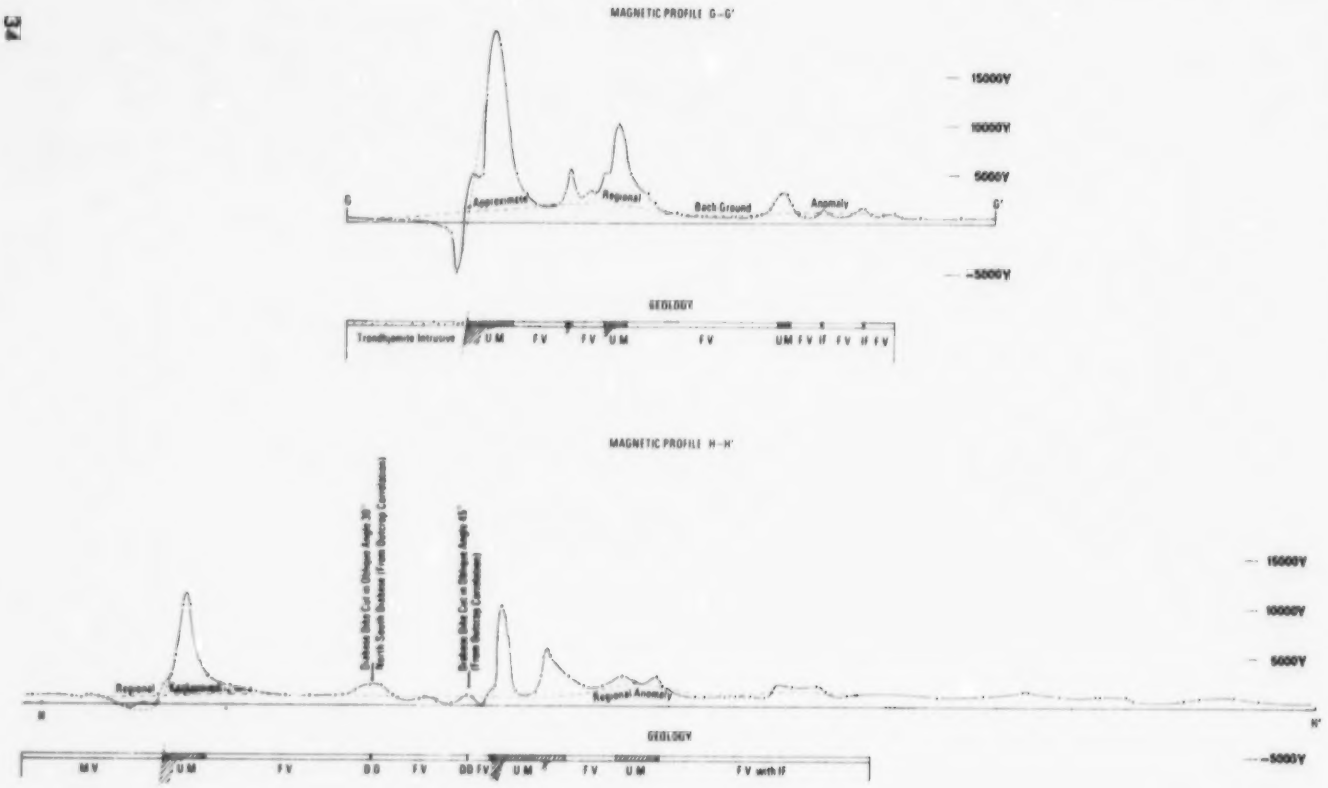

Figure 31–Vertical field magnetic profiles across ultramafic and metavolcanic sequences. The location of the profiles is shown on the magnetic contour map (Chart, back pocket).

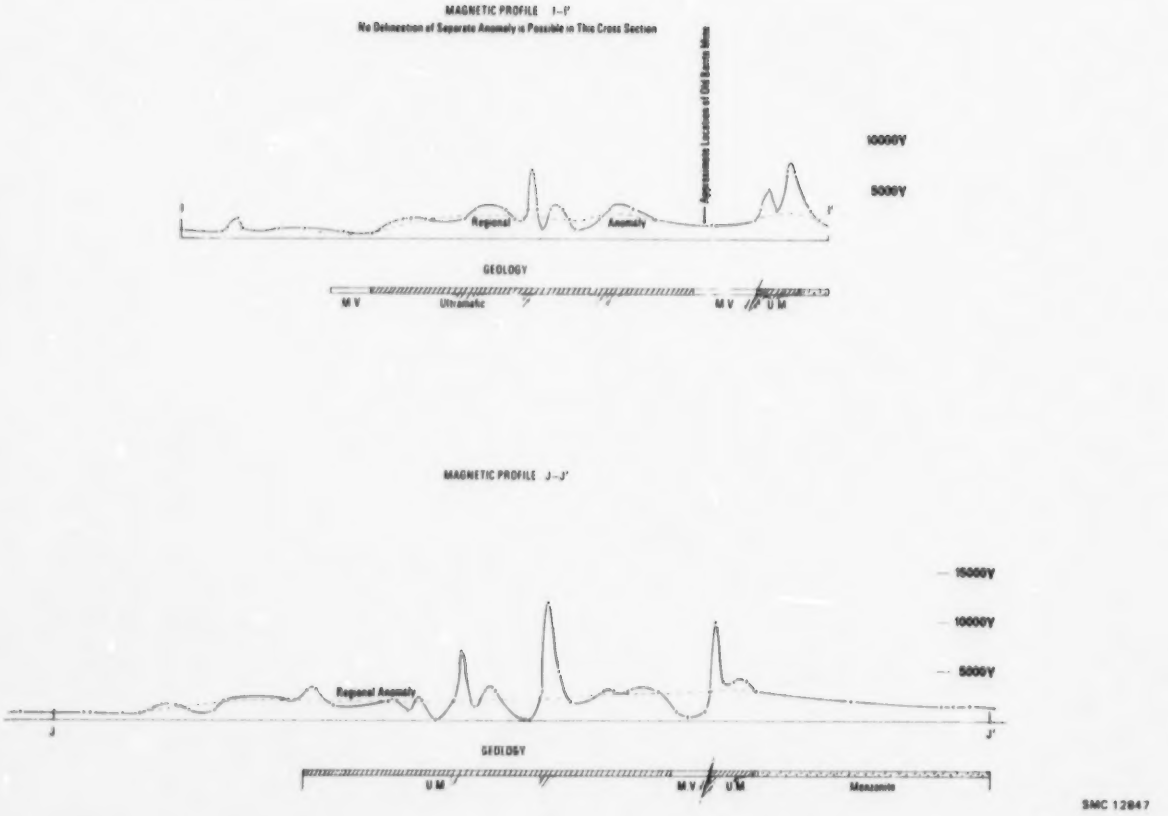

Figure 31–Vertical field magnetic profiles across ultramafic and metavolcanic sequences. The location of the profiles is shown on the magnetic contour map. (Chart, back page).

thickness of the ultramafic mass. The ultramafic anomalies along St. Peter Bay do not have vertical field intensities over +3000 γ. This is due to the thick overburden, which attenuates the amplitude and cuts off the high frequency components of the anomaly. Six cross section profiles of magnetic anomalies were prepared for Langmuir Township. Four profiles (G-G′, H-H′, I-I′, J-J′) cross ultramafic rocks and are shown in Figure 31. The profiles along the Eldorado-Langmuir Township line (Figure 28, C-C′) and the diagonal line (Figure 28, D-D′) (N45°W) in Langmuir Township, based on ground magnetic data, were analyzed for wavelength study.

Profiles G-G′, H-H′, I-I′, and J-J′ indicate a regional anomaly across the ultramafic intrusions, but these seem to be very limited in width and thickness. The ultramafic masses in the northwestern third of Langmuir Township are narrow compared to those in the southern part of the township.

For quantitative analysis of the dimensions of the ultramafic intrusions, two types of two-dimensional models were tried for curve fitting. The ribbon model method, described by Grant and West (1965) was tried for the anomalies in profiles G-G′ and H-H′. The regional magnetic inclination used was 77.5°, and the strike angles from the magnetic meridian were obtained from the magnetic map. The quantities $W_{1/2}$, $W_{1/3}$, W_m, K, and the slopes of the magnetic anomalies were measured from the profile. However, this type of model could not be fitted to the anomaly curves with any acceptable agreement. Next, the sloping step model for faults was tried for the trondhjemite-ultramafic contact in profile G-G′. A magnetic inclination of 70° and a strike from the magnetic meridian of 50° were used. Although a good matching of curves was not obtained, the contact does seem to be faulted and to dip 55°-75°N. A meaningful value for the throw was not obtained from the fault model.

As can be seen in Figure 31, the anomalies in the profiles I-I′ and J-J′ are not separable for quantitative analysis. However, the following points are observed in Langmuir Township: (a) the regional magnetic anomaly intensity rises as high as +1500 to +2000 γ for most areas underlain by ultramafic rocks; (b) the dips of the ultramafic intrusive rocks in the northwest quarter of the township seem steeper than those in the southern part; (c) the width of the ultramafic anomalies in the northwestern part of the township seems narrower than in the southern part; the ultramafic mass in the south seems to be deeper and wider, as can readily be seen from the greater amplitude and longer wavelengths of the regional magnetic anomaly in that part; (d) all four profiles across the ultramafic masses (Figure 31) show at least two grouped anomalies about ¾ to 1¼ miles (1.2 to 2 km) apart, with the peaks of the anomalies exceeding +5000 γ in all cases. An explanation of this fact may be that the very irregular ultramafic masses are fed by two parallel dike shaped (or sill type) sources along fractures.

The trondhjemite intrusion near the Eldorado-Langmuir boundary has a rather uniform magnetic field intensity of about +700 γ, whereas the monzonite mass near the southeastern boundary of Langmuir Township has an average field intensity of greater than +1000 γ.

The magnetic characteristics of each lithologic unit in the two townships are generally identical. However, the granodiorite in the southwestern quadrant of Eldorado Township has a magnetization of about +900 to +1000 γ near the southern boundary. This value increases on the north side of each of the north-

east-trending diabase dikes; near the southern dike the values are +1100 to +1200 γ, and near the northern dike +1200 to +1500 γ. This phenomenon may be explained by the assumption that the diabase is sloping and thereby causes high magnetization at depth raising the background field level. It is also possible that there is a system of faults associated with these diabase dikes. This hypothesis, which also agrees with the gravity model described previously, permits the postulate of a steplike basement of lithologic units with different magnetization. This seems true in the northeastern quarter of Eldorado Township. The trondhjemite on the south side of the two diabase dikes has a magnetic field level averaging +700 γ while on the north side of the southern diabase dike, the average level is +900γ. Therefore it can be assumed that a step in the basement occurs with each diabase dike.

The metavolcanic units in Eldorado Township are the same as those of Langmuir Township. They are not distinguishable from each other by intensity of magnetization. An interesting fact in the survey area is that the ultramafic rocks are closely associated with the felsic volcanic rocks except in the southern part of Langmuir Township. If the volcanic sequence in the area follows the traditional cycle of mafic volcanic rocks at the bottom and felsic volcanic rocks at the top of the volcanic pile, but the ultramafic rocks intrude through the complete sequence, the following hypothesis may explain the situation.

The area where the ultramafic rocks are closely associated with the felsic volcanic rocks is probably where the fault blocks subsided relative to the adjacent areas and survived the pre-Timiskaming, pre-Huronian and other erosional periods in the geological history of the area. For the areas where the ultramafic rocks are in direct contact with the mafic volcanic rocks, it is assumed that the area was uplifted, and the felsic volcanic rocks overlying the mafic volcanic rocks were eroded away. This hypothesis may be applied on a regional scale as briefly shown in the gravity anomaly interpretation.

The fault blocks uplifted relative to the areas north of the Porcupine-Destor Fault and south of the most northerly diabase dike in Eldorado Township are in the parts of Adams, Shaw, and Carman Townships where the ultramafic rocks are generally associated with the mafic volcanic rocks. In Eldorado-Langmuir Townships, south of the above diabase dike, the felsic and ultramafic volcanic rocks are well exposed contrary to the situation in the area north of the dike. In line with this hypothesis, the ultramafic rocks in southern Langmuir Township and the northwestern corner of Eldorado Township were deep seated at one time and later lifted up for erosion, losing most of the felsic volcanic sequences. This structural hypothesis also has significance in the search for ore mineralization in the area, since some types of mineral deposits are closely related to a certain period in the volcanic sequences.

The most massive anomalies caused by ultramafic rocks occur in the centre and the northwestern part of Eldorado Township and have a large amplitude and long anomaly wavelength. In the south-central and the southeastern quarter of Eldorado Township there are numerous small anomalies with amplitudes over +2000 γ and with small geometric dimensions. These small anomalies may be due to thin iron formation bands or small masses of ultramafic rocks. In Eldorado Township only a few, north-trending, Matachewan-type, diabase dikes crop out. The north-south diabase anomalies have, as in Langmuir Township, low ampli-

tudes relative to regional anomalies. Two parallel, N50°E - N60°E trending diabase dikes appear quite distinctly on the magnetic map, and the +2000 γ contour outlines them very well. According to Pyke (verbal communication, 1971), these dikes have a nearly vertical dip. From the surface geology (Pyke 1970) it can be seen that these diabase dikes are offset in a very irregular manner by the north-northwest striking faults in the central part of the township. However, from the magnetic map, this detail cannot be traced closely due to the nearby ultramafic anomalies. The separation of a particular anomaly from the background regional anomaly is very difficult in this area.

WAVELENGTH SPECTRUM ANALYSIS

To investigate the depth range and the spacing of the magnetically anomalous geological features, the wavelength spectra of the one-dimensional profiles in the area were obtained. The finite length data, f(x), from the profiles were sampled at three convenient spacings; 439, 100, and 50 feet, and the wave number domain spectrum was obtained with the mathematical formula:

$$F(u) = \int_{-\infty}^{+\infty} f(x)_e^{-i2\pi ux}\, dx \qquad (6)$$

where u is the wave number in cycles per unit length along the profile axis x.

As shown in Figure 32, the anomalies due to shallow magnetic material of small dimensions and those due to deep bodies with large dimensions have different characteristics as to amplitude (A_1, A_2) and wavelengths (λ_1, λ_2). From the profile, the amplitudes can be read directly without too much difficulty, but the wavelength component is difficult to see readily in the complex real profile. The anomalies due to small magnetic bodies at shallow depth will be short, whereas anomalies produced by a magnetic body of the same size at great depth will be attenuated and disappear into the background level. Large magnetic bodies on the other hand, will produce long wavelength anomalies regardless of the depth. Even at great depth, a large magnetic body will have a wavelength anomaly similar to the one caused by a shallow body. At shallow depth, the amplitude of the anomaly will increase greatly, but the wavelength will remain relatively unchanged. The basic idea of anomaly wavelength analysis is illustrated in Figure 32.

To use another method of potential field data reduction, the design of an appropriate mathematical filter could be considered. However, being interested in the characteristic wavelengths of magnetic anomalies in one particular direction only, designing a filter would have little merit in this case.

If there is a regularity in the spacing of an anomaly it will show in the wavelength spectrum as well as in the frequency spectrum, except for special cases where the magnetic body covering the surface is completely flat. But such an unusual case can usually be detected by examination of the surface geology. The theory and the algorithm of the Finite Fourier transform is widely used by many geo-

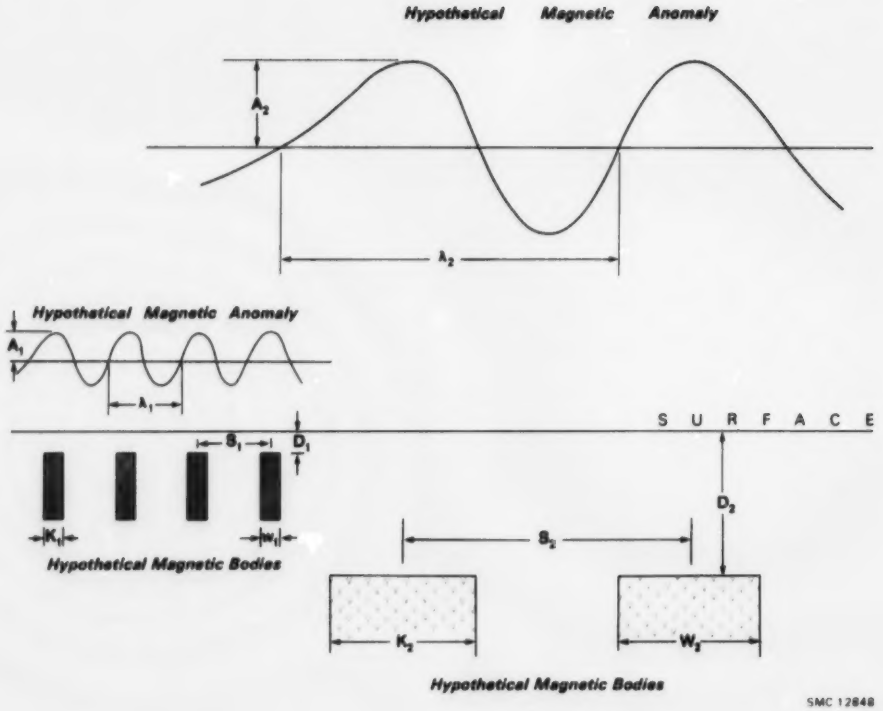

Figure 32–Schematic diagram showing the wavelength analysis model.

physicists in data reduction today and it will not be repeated here. A flow chart of the computer program is given in the Appendix. The spatial data used are real values and even-numbered in length, and their Fourier transforms are also real and even. The spectrum from the regional profile A-A′ (in Figure 28), with a data interval of 439 feet (134 m) is not shown, because it does not reveal much information except that the response is very smooth and it decreases at high frequency (cycles per data spacing) by about 2db from that of low frequency.

The magnetic anomaly power spectrum from the profiles along the Eldorado-Langmuir Township line (Figure 28, C-C′) and the diagonal profile (N45°W) in Langmuir Township (Figure 28, D-D′) sort out the following magnetic anomaly wavelengths;

North-South profile along Eldorado-Langmuir Township line (C-C′)	N45°W profile through center of Langmuir Township (D-D′)
3200 ft. (975 m)	4800 ft. (1463 m)
	3100 ft. (945 m)
1580 ft. (482 m)	2900 ft. (884 m)
	1490 ft. (454 m)
1051 ft. (320 m)	1470 ft. (448 m)
	1110 ft. (338 m)
780 ft. (238 m)	1080 ft. (329 m)
770 ft. (235 m)	880 ft. (268 m)
635 ft. (194 m)	720 ft. (219 m)

Considering the finite length of the data and the association of the low frequency component with the background anomaly level, the anomaly wavelengths over 3,000 feet (910 m) are regarded as unimportant in the present analysis. The anomaly wavelengths ranging from 1,000 (305 m) to about 1,580 feet (480 m) are interpreted as having been produced by the geometric arrangement of the ultramafic sources as mentioned earlier in this report. As seen from the profiles in Figure 31, the ultramafic magnetic anomalies have a general background level which may be due to their irregular near-surface distribution. They also have at least two anomaly peaks in each profile representing the sources with parallel strike and at a relatively regular spacing of 1,000 to 1,500 feet (305 to 457 m) within the previously described two grouped anomalies. Since the profiles for the wavelength analysis were taken in almost the same direction, the two interpretational results on the ultramafic source spacing agree very well. The geological shape of the ultramafic bodies (e.g. dikes, sills, etc.) cannot be determined exactly. However, it seems from the surface anomalies that the ultramafic intrusions in the survey area were originally steeply dipping dikes cutting complete sequences of volcanic rocks in the area. After this intrusive stage, they were cut and mobilized mechanically, interrupted by erosional periods, by faults of different ages and nearby late felsic intrusives. Therefore, the anomaly wavelengths of 1,000 feet to 1,500 feet (305

to 457 m) probably represent the previously mentioned ultramafic source spacings within the anomaly groups spaced ¾ to 1¼ miles (1.2 to 2 km) apart.

The ranges of 635 to 800 feet (194 to 244 m) anomaly wavelength are probably produced by the folding and fault patterns striking in a northeast direction. However, from the magnetic map, it is impossible to recognize folds of this size. Faults striking parallel and close to diabase dikes in the area where these profiles were taken are very difficult to recognize, as is the case in geological mapping. The surface geological map by Pyke (1970) was studied closely but no correlations were found.

In conclusion, the magnetic anomaly wavelength analysis suggests a tendency for repetitive geological structure or lithologic sequences, with spacings ranging from 800 to 1,500 feet (244 to 457 m). In particular, the wavelength anomaly of 1,000 to 1,500 feet (305 to 457 m) is suspected to be due to ultramafic intrusive rocks with an interval range of 1,000 to 1,500 feet (305 to 457 m) producing high amplitudes. However, the potential field anomaly wavelength analysis should be pursued further in future surveys for a better understanding of the Precambrian Shield.

INTERPRETATION OF OVERBURDEN EFFECTS

In the survey area, as mentioned before, the overburden effect has attracted particular attention in north-central Langmuir Township where the overburden thickness is greater than 100 feet (30 m). However, during the process of interpretation it was found that the separation of a particular magnetic anomaly from the regional anomaly was extremely difficult even where the overburden thickness was less than 50 feet (15 m) because of the high background noise level of the survey, and it would be pointless to try to deconvolve the overburden effect for the anomalies under thick overburden. In theory, the downward continuation of magnetic fields could be used to increase the resolution of weak anomalies above thick overburden. The basic theory is well explained in the text by Grant and West (1965, chapters 8 to 11) and it will not be repeated here. However, there is a more operational method utilizing the computer which can be conveniently used in practice and has been described by Dean (1958) and Bhattacharyya (1972).

This procedure has not been applied to the present magnetic survey data, because they were obtained on a grid system designed to help in outlining geological features, and it would have been too costly to convert them into an operational grid system suitable for computer application.

STRUCTURAL GEOLOGY

The structural geology of the survey area was investigated in the following ways:

(1) Matching of 46 fault model curves of a flat faulted bed with four thickness and nine displacement values, assuming isotropic magnetic material, against the three-dimensional magnetic anomaly model curves calculated

by Lehmann (1970) (Magnetic susceptibility contrast obtained from Table 1).

(2) Study of the dislocation of magnetic lineation.
(3) Correlation with the detailed surface geology maps by Pyke (1969 and 1970).
(4) Study of the magnetic anomalies caused by the iron formation as a key horizon. However, because of erratic occurrences, less weight was given to the Iron Formation.
(5) Tracing of diabase dikes and outlining of ultramafic intrusions.
(6) Information on faults observed in the surrounding area.

The geological structure maps of Eldorado and Langmuir Townships shown on the chart (back pocket) are the result of these studies. On this chart, only the faults and diabase dikes are shown. This has been done for the following reasons: Although the ultramafic rocks, iron formations and diabase dikes can be mapped from the magnetic contours, the detailed boundaries of the lithologic units can be, and have been, more accurately determined by surface mapping. Therefore, it was not attempted to retrace these boundaries. The diabase dikes, however, are shown because they are believed to have great importance in the structural geology of the area and are considered to be closely related to its fault systems.

In the author's opinion, there are at least three types (and/or periods) of fracture or fault patterns in the area. One of the earliest types is a north-south trending low pressure fracture system now occupied by diabase dikes. A second fracture system runs parallel to the northeast striking diabase dikes (Keweenawan type according to Pyke, 1970). The Porcupine-Destor Fault, striking in the same direction, is believed to be younger than these dikes. However, the regional gravity anomaly described earlier shows evidence of either an anticlinal structure trending through Shaw, Carman, and Deloro Townships or an uplifted block of granitic mass underlying the metavolcanic rocks in these townships. If this hypothesis is acceptable, the northeast-trending fracture system could be related to the Porcupine-Destor Fault.

The third system consists of north to northwest-striking fractures which seem to cut the northeast-trending faults. The extension of the Burrows-Benedict Fault into the west half of Eldorado Township is one example. These faults are especially prolific in west-central Eldorado and in central Langmuir Townships. Other small faults are present, but the relative age could correlate with any one of the above types.

The structural geology of the ultramafic rocks is still under debate and deserves a further comment. The magnetic profiles G-G′, H-H′, I-I′, and J-J′ (Figure 31 across the ultramafic masses show consistently higher field gradients on the positive portion of the anomalies than on the negative one. This indicates that the ultramafic rocks are dipping north (with an approximate dip angle greater than 60°N) in most cases. From this observation and from the fact that the predominant wavelengths of the ultramafic anomalies are 1,000 to 1,500 feet (305 to 457 m), and the ultramafic anomaly spacings are roughly ¾ to 1¼ miles (1.2 to 2 km), we can conclude that the ultramafic masses in the survey area are fed by dikes (or sills) that dip nearly vertically but slightly to the north, and that the dikes (or sills) occur at preferred distance intervals of ¾ to 1¼ miles (1.2 to 2 km). From the wavelength analysis data, we can assume that they contain steeply dipping folds

or have parallel branch dikes which produce secondary magnetic anomalies with distance intervals of 1,000 to 1,500 feet (305 to 457 m). However, this should be studied further in more detail.

There is one more point to be mentioned with respect to the northeast-trending diabase dikes (Keweenawan or Abitibi type). In Eldorado Township, there are two parallel Abitibi type dikes striking approximately N50°E to N60°E. In the southwestern part of the township, the magnetic field level rises from 900 - 1000 γ south of the two dikes to 1000 - 1200 γ between the two, and further to 1200 - 1400 γ north of the northern dike. However, the whole area is mapped as granodiorite. A similar configuration of the magnetic field is observed again in the northeastern corner of Eldorado Township where trondhjemite has been mapped. These observations may be used as evidence that the Abitibi type diabase dikes follow the above mentioned second northeast striking fault system. The assumption seems reasonable that the difference in magnetic field background can be directly correlated to the structural displacement in the area.

According to the geological survey by Pyke (1970) there are few fold structures present. Moreover, the interpretation of folding from the magnetic map is difficult. In the case of a gravity field, the potential is produced by monopole sources (mass). A magnetic field, on the other hand, is produced by magnetic dipoles, and the increased number of undetermined variables in models of fold structures make the interpretation of a magnetic map in this regard extremely time-consuming and almost meaningless. Therefore, it is not attempted in this report.

RECOMMENDATIONS ON GEOPHYSICAL METHODS

As can be seen from Table 1, the magnetic survey method can be used for the mapping of ultramafic rocks, diabase dikes, and iron formation, as these rock types have relatively high magnetic susceptibilities. The resistivity of overburden varies very much as shown in Table 2, but in the prospecting for base metal sulfide ores, the combination of ground magnetic survey and electromagnetic methods as it is practiced by many geophysical companies should be effective. After a possible conductive ore zone has been outlined, the induced polarization method may be used for a detailed survey.

The gravity method is not very suitable for the structural mapping of ultramafic rocks in the area. As shown in Table 3, the ultramafic rocks in the survey area have a relatively low specific gravity, comparable to the one of granitic intrusives, and it can be assumed that the small density contrast between them and the metavolcanic rocks will produce very weak gravity anomalies. The low specific gravity of the ultramafic rocks in the survey area is probably due to heavy serpentinization and other possible alterations. One case history for a gravity survey in an ultramafic environment in Semple Township, south of Timmins, Ontario, can be found in the Ontario Division of Mines Assessment File No. 2,546.

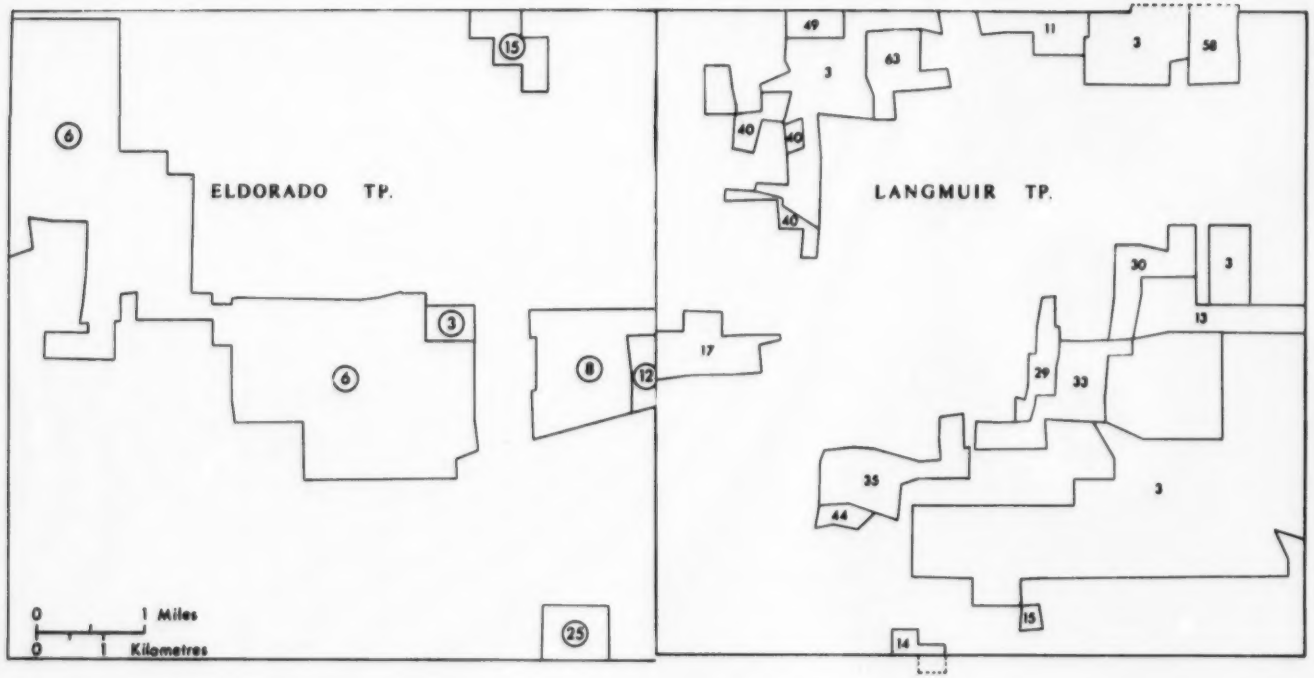

Figure 33–Claim location map of Eldorado and Langmuir Townships, August 1973. Property numbers as shown in Table 5.

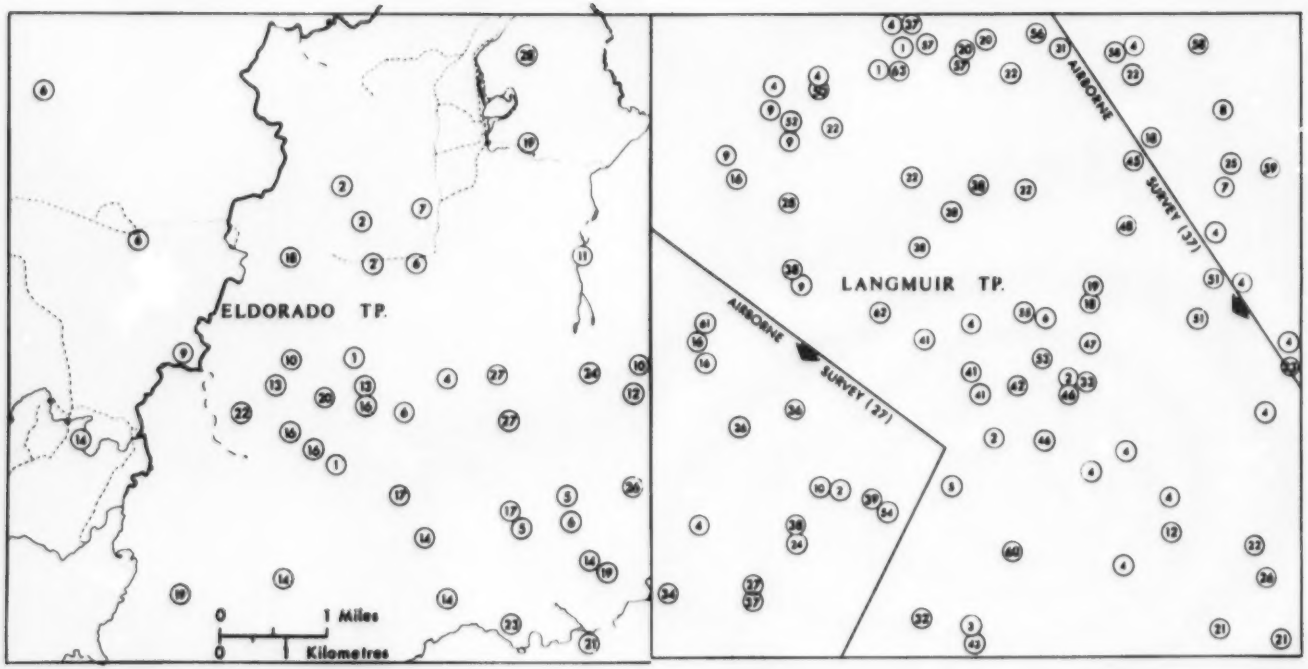

Figure 34–Assessment and information location map of Eldorado and Langmuir Townships. Property numbers as shown in Table 5.

Table 5 ASSESSMENT WORK ON FILE IN THE ASSESSMENT FILES RESEARCH OFFICE, ONTARIO DIVISION OF MINES, TORONTO AS OF MAY 31, 1973

NAME ON FILE	ASSESSMENT FILE NUMBER
ELDORADO TOWNSHIP	
Abacus Mines Ltd.	DD10, 63.1009*
Acme Gas & Oil Co. Ltd.	DD27, 63.2266
Black River Mining Ltd.	63.1937
Cadamet Mines	DD19
Canadian Nickel Co. Ltd.	DD16, DD25, DD26, 63.2751, 2.371, 2.441, 2.654, 2.832, 2.870
Chance Mining & Exploration Ltd.	63.2135
Draper, R. S.	63.2543, 2.643
Falconbridge Nickel Mines Ltd.	63.1125, 63.2718
Gilbert, J. A.	63.1841
Golata Claims	DD22
International Nickel Co.	DD28, DD29
Lang, B. W. (Acme Gas & Oil Co.)	63.2044, 63.2249
MacFarlane, R. T.	DD11, DD14
McWatters Gold Mines Ltd. (Terrex Option)	63.1945, 63.2552
Mercury Investors	63A.62
Mespi Mines Ltd.	63.1400, 63.2871
Mining Corporation of Canada	63.1934, 63A.471
Newmont Mining Corporation of Canada	DD18
Noranda Exploration	DD12
North Slave Mines	63.2245
Pyrotex Mining	DD23
Terrex Mines	DD15
Urban Quebec Mines	DD17, 63.2388
Persons Unknown	DD13
LANGMUIR TOWNSHIP	
Accra Exploration Limited	DD23, 63.1430, 63G.5
Camisso, A.	63.2579, DD13
Canadian Johns Manville Co. Ltd.	DD11
Canadian Nickel Co. Ltd.	DD34, DD37, DD38, DD43, DD44, 63.2596, 2.509, 2.654, 2.659, 2.721, 2.724, 2.831
Canadian Superior Exploration Ltd.	DD13
Cantri Mines	DD25
Claw Lake Molybdenum Mines Ltd.	63.2635
Con-Key Mines	63.1980
Con-Shawkey Option	DD26, 63.2060
Cooper, G. E.	DD15
Dominion Gulf Co.	63.273
Falconbridge Nickel Mines Ltd. (Galata Option)	DD30, 63.1152, 63.2718
Garfield Apprais s Ltd. (J. R. B. Parres)	63.2794, 63.2795
Globe Exploration & Mining	63.1714
Gomar Mines	DD32, 63.1429, 63G.1
International Kenville Gold Mines	63.1843, 63.2015
International Nickel Co.	DD36, DD40, DD41
Kidd Mining Co. Ltd.	63.1792
Kosciuszko	DD29
Lacanex Mining Co. Ltd.	DD20
Lake Kosack Mining Limited	63.1977
Lang, B. W.	63.2044
Larchmount Mines Ltd.	63.1881
Marvel Minerals	DD39
Maybrun Mines	63.1484, DD35
Maycor Mines	63.2877, 2.366
Magoma Mines Ltd.	63.1493
McWatters Gold Mines Limited	DD21, 63.1171
Mespi Mines	63.1400, 2.126
Mining Corporation of Canada Limited	DD42, 63.15591, 63.1635, 63.202, 63A.453
Min-Ore Mines Limited	63.1741
National Explorations Limited	DD24, 63.1797
Newrich Exploration Limited	63.1715
Nicolet Asbestos Mines	DD10
North Crescent Explorations Ltd.	63.1476
Northwest Canalask Nickel Mines (Mid-North Expl.)	DD28, 63.2005
Northwest Canalask & Maycor Mines	DD27
Ourgold Mining Co. Ltd.	63.2004
Paramaque Mines Ltd.	63.1645
Peerless Canada Exploration Ltd.	DD31, 63.2039
Rouyn Merger Mines	DD22
Seaway Copper Mines	63.2885
Scope Mining & Exploration Consultants	DD16
Silverplace Mines Ltd.	DD18
Straus Exploration Inc. (Drake, K. H.)	63.2504
Summ. Exploration & Holdings Ltd.	DD19, 63.2699, 63.2925
Tex-Sol Explorations Ltd.	DD14, 63.1737, 63.2621
Tinex Exploration and Development Ltd.	63.1636
United Porcupine Mines Ltd. (Cravit, H.)	63.1823
Urban Quebec Mines Ltd.	DD12
Waco Petroleums Ltd.	DD17
Xtra Developments Inc.	63.3041

*DD stands for Dia. ..ad Drill file.

MINERAL EXPLORATION AND MINING ACTIVITIES

Prior to the initial exploration for nickel by McWatters Gold Mines Limited in 1962, the area was prospected primarily for gold. A limited amount of barite was mined intermittently from 1911 to 1941 in the southern part of Langmuir Township. Narrow asbestos veins occur in serpentinized ultramafic rocks. Since the discovery of nickel in 1964 by McWatters Gold Mines Limited, the major interest of the area has centered around the nickel mineralization associated with the serpentinized ultramafic rocks. The nickel deposit discovered by The International Nickel Company of Canada Limited and being developed by Noranda Mines Limited is located on claim P-70585 in a block totalling 97 claims. According to E. Gallo of Noranda Mines Limited (personal communication) the following information pertains to the Noranda-Inco ore body:

> The ore reserves total 1.5 million tons grading 1.87% Nickel. The ore zone consists of a lenticular body of disseminated and massive sulphides. The disseminated sulphides are more predominant, with pyrrhotite being the predominant sulphide mineral. Pyrite is also present with lesser amounts of pentlandite and chalcopyrite. The ore zone occurs in, at, or near the contact of a peridotite intrusive with greenstones. It has been fairly well outlined along strike but has not been delimited entirely at depth.

Currently, Noranda Mines Limited is completing a new shaft to develop the nickel deposit.

In 1971, claims in good standing covered the whole of Langmuir and Eldorado Townships except the southwestern corner of Eldorado Township. The mining companies engaged in exploration in 1971 were The International Nickel Company of Canada Limited, Noranda Exploration Company Limited, Canadian Jamieson Mines Limited, as well as a few independent prospectors.

The International Nickel Company of Canada Limited was conducting geological, magnetic, and ground electromagnetic surveys in the area during the field season.

APPENDIX

Flow chart of main program for wavelength spectrum analysis.

START

Read NJOB (Profile number)
DELTA (Data interval)

Read length of Profile (even number)

Call Subroutine DBPLOT
plotting of data profile

Call Subroutine FOUR 2
Numerical Fourier transform
in spatial domain

Write the Real and Imaginary
parts of transformed values

Calculation of amplitude and wavelength

Call Subroutine DBPLOT
plotting of wavelength spectrum

END

* Note: For subroutines FOUR 2 and DBPLOT, references IEEE Transactions, 1967 and McCracken 1965.

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